NAVAL OCEANOGRAPHY ANTISUBMARINE WARFARE CENTER YOKOSUKA, JAPAN

FORECASTER’S HANDBOOK

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CHAPTER 1
Basic Description

1. Command Mission. The mission of the Naval Oceanography AntiSubmarine Warfare Center Yokosuka, Japan (NAVOCEANASWCEN YOKOSUKA JA, further abbreviated NOAC Yokosuka) is to provide asymmetric warfighting advantage for Antisubmarine (ASW) forces in $7^{th}/5^{th}$ Fleets through application of oceanographic sciences; and accurate and timely weather forecasts, warnings and recommendations for Commander, Naval Forces Japan (CNFJ) ashore forces to facilitate asset protection responsibilities and risk management.

2. Location and Description.

a. Fleet Activities Yokosuka is located on the eastern side of the Miura Peninsula, on the island of Honshu (the largest of the four main Japanese islands) at 35° 17’N , 139° 40’E, , see figure 1-1. The base is approximately 26 miles (42 km) south-southwest of Tokyo, Japan. NOAC Yokosuka is a tenant command to Commander, Fleet Activities Yokosuka (CFAY) and is bordered to the north and east by Tokyo Bay, or Tokyo Wan in Japanese.

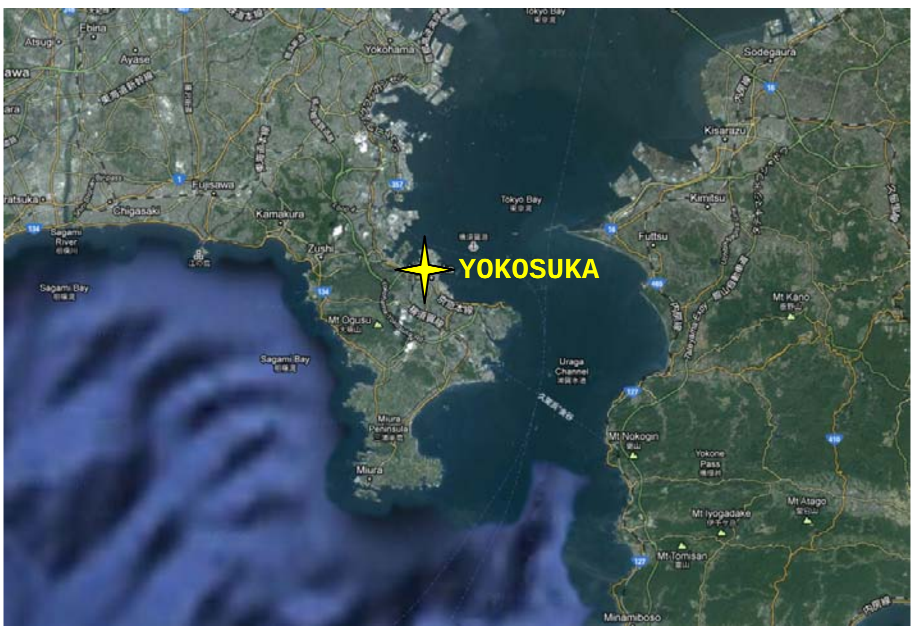

FIGURE 1-1. LOCATION OF FLEET ACTIVITIES YOKOSUKA

b. Fleet Activities Sasebo is located at 33.16°N latitude and 129.72°E longitude, in the Nagasaki Prefecture of Kyushu, see figure 1-2. The physical property of Command Fleet Activities

Sasebo (CFAS) consists of eight separate facilities, spanning over 40 square miles and covering almost 900 acres. The base occupies nine separate land areas, three industrial, two ordnance, and one remote housing area. Fleet Industrial Supply Center operates three fuel terminals and seven deep water berths. Port Operations is physically located on the east side of Juliet Basin on the northern end of Sasebo Bay.

FIGURE 1-2. FLEET ACTIVITIES SASEBO

3. Command Organization. NOAC Yokosuka is an Echelon V command responsible for two detachments.

a. Naval Oceanography Antisubmarine Detachment (NOAD) Kadena is located at Kadena Air Base on the island of Okinawa. NOAD Kadena’s mission is to provide asymmetric warfighting advantage for Patrol Reconnaissance Wing One Detachment and Tactical Support Center, Kadena through the application of oceanographic sciences.

b. NOAD Misawa is located at Misawa Air Base near the northern tip of Honshu, Japan. NOAD Misawa’s mission is to provide asymmetric warfighting advantage for Commander, Patrol and Reconnaissance Forces Fifth and Seventh Fleets through the application of oceanographic sciences.

4. Supported Commands. NOAC Yokosuka provides resource

protection (RP) for CNFJ ashore forces. In addition, NOAC Yokosuka supports Commander Task Force 74 (CTF-74), as Theater ASW Commander, and Commander Destroyer Squadron 15 (CDS-15) as Strike Group ASW Commander.

5. Meteorological Instruments and Equipment.

a. Precision Aneroid Barometer (ML-448/UM). The precision aneroid barometer is used as the primary pressure sensing instrument at NOAC Yokosuka and is mounted on the RP watchfloor at 174 feet above mean sea level.

b. Automatic Surface Observation System (ASOS). The ASOS consists of a remote sensing station atop the Yokosuka Heliport Control Tower (building H-1632). The display units are located on the NOAC Yokosuka RP watch floor, the Yokosuka Heliport Tower, and Port Operations facility (building 5203). Remote information is available on the command website. The remote sensing equipment monitors ambient air temperature, dew point, relative humidity, wind direction and speed, rainfall, visibility, and cloud heights. The video display units show current temperature and dew point, maximum and minimum temperatures, 2 minute average wind direction and speed, and peak wind.

c. Davis Meteorolgical Sensing System. NOAC Yokosuka’s Davis sensor is located on the roof at 239 feet above sea level. There are two Davis Senors located at CFAS; one atop of building 98 and one at Iorzaki Fueling Station (building 600), on the northwest side of Sasebo Bay. The sensor suite includes a rain collector, temperature sensor, humidity sensor, anemometer, solar radiation sensor (to determine amount of cloud cover). The Sensor Interface Module (SIM) collects outside weather data from the sensor suite then transmits the data to the Weather Display Console on the NOAC Yokosuka RP watchfloor and the Sasebo Port Operations watchfloor.

d. Vaisala Automatic Weather Station. The Vaisala system is located outside of the CFAS Headquarters building. Its sensor suite measures wind speed and direction, pressure, temperature, relative humidity, and precipitation. The Vaisala graphical display is capable of displaying current and past weather data (up to 30 days in graph form). It includes wind speed and direction, gusts, temperature, barometric pressure, humidity, heat index and wind chill, dew point, wet bulb, and rainfall. It also has a lightning detector which can display current data and a history of up to 96 hours.

e. Supplemental Weather Radar (SWR)(AN/FPS-131). The AN/FPS-131 SWR is a Doppler radar located on CFAY approximately 100 yards southwest of NOAC Yokosuka and provides unobstructed, real-time detailed displays of potentially severe weather systems developing or moving within a 300-mile radius of Yokosuka. The SWR computer generates a large variety of analytical products including storm intensity and movement, time-lapse animation, rainfall accumulation rates, vertical cross-sections for storm structure analysis, storm height, turbulence, wind shear, and velocity information and the display is located on the NOAC Yokosuka RP watchfloor. The system can dissect and provide multi-dimensional outputs of these detailed weather features within a 120-mile radius.

f. METOC TV. METOC TV is sponsored by Navy Gateway Inns and Suites (NGIS) and operated by ONE-Net and contains a slide show of a five-day forecast, current operservations, a SWR and satellite loop, on Americable channel 16. Current weather warnings are posted on METOC TV when issued for CFAY and CFAS.

g. Meteorological Satellite Availability. The Satellite Receiving Equipment (FMQ-17) Terrascan receives high-resolution imagery from a variety of geostationary and polar orbiting satellite systems. The antenna is located in the NOAC Yokosuka upper parking lot and satellite data is monitored on the NOAC Yokosuka RP watchfloor.

(1) Geostationary Satellites. The MTSTAT-2 provides full disk and northern hemispheric visible, infrared, and water vapor imagery which is updated hourly. Visible imagery is limited to daylight availability. Hemispheric imagery is available every three hours. MTSAT-2 is the current geostationary satellite available for use by NOAC Yokosuka.

(2) Polar Orbiting Satellites. Five National Oceanic and Atmospheric Administration (NOAA) satellites, 17 and 18, and Defense Meteorological Satellite Program (DMSP) are currently available for use by NOAC Yokosuka forecasters.

6. Services and Products.

a. The NOAC Yokosuka website provides current weather information and a five day extended outlook to include sky conditions, weather, surface winds, and maximum and minimum temperatures. This web page, updated several times throughout the day, also includes all weather warnings and advisories in effect for CFAY and CFAS, tropical cyclone information (when applicable), solar, lunar, and current radar and satellite imagery. The information can be viewed at: http://www.usno.navy.mil/NOOC/noac-yokosuka/ for CFAY and CFAS.

b. In accordance with reference (b), weather advisories/warnings for thunderstorms, winds, and snow accumulation are issued to all naval units located ashore in the Yokosuka/Yokohama and Sasebo area, as well as to Navy and other ships (when specified) at anchor, moored, or arriving/departing the Yokosuka/Yokohama and Sasebo area. All warnings are issued as far in advance as possible to provide ample notice of hazardous or destructive weather phenomena. Because of the variability of terrain surrounding the port of Yokosuka and Sasebo, wind warnings cover both protected and exposed areas.

c. ASW Products. ASW products are produced, used, and interpreted routinely by NOAC Yokosuka personnel for operational support primarily to CTF-74/54 and CDS-15. Forecasters should have a thorough knowledge of ASW products and the procedures for producing and requesting these products. The Naval Oceanographic Office (NAVO) Reach Back Cell (RBC) is the main provider to the U.S. Navy for oceanographic data. The RBC has a long list of products and data available. Some examples of products are Tactical Oceanographic Analysis (TOA), Tactical Oceanographic Features Analysis (TOFA), bathymetry charts, and Performanc Surface Maps (PS-Maps). NOAC Yokosuka provides analysis briefs using NAVO products, mainly using the systems, software and databases outlined below.

(1) Interactive Multi-sensor Analysis Training System (PC IMAT). Computer based and “stand-alone”, PC-IMAT is a concept/context based software program with the capability of forecasting detection ranges in the ocean using active and passive sonar. This Tactical Decision Aid (TDA) integrates high-fidelity physics-based models and databases and provides conceptualization and visualization of complex phenomenon, including 3-dimensional modeling and animation, coupled with scientific visualization techniques. Recent oceanographic model data or bathythermograph data is ingested into the program before conducting computations. In addition to its operational use, it is also a good acoustic training tool. It utilizes curricula designed to support conceptual understanding rather than memorization. This environmental understanding and its relationship to underwater acoustic prediction problems enhance reasoning skill development.

(2) Navy Coastal Ocean Model (NCOM). The forecast model data used in PC-IMAT is called the Navy Coastal Ocean Model (NCOM). NCOM has many outputs, including graphics that depict numerous amounts of information concerning oceanographic conditions around the globe. The following is a list of products created by NCOM in a graphical format (gif):

(a) Temperature at a selected level

(b) Sonic Layer Depth

(c) Depth Access

(d) Critical Depth

(e) Deep Sound Channel Axis

(f) Mixed Layer Depth

(g) Sound Velocity at a selected level

(h) Fronts & Eddies

NCOM data output is also available in a text file, or wavelet, which can be ingested into PC-IMAT for processing and acoustic analysis.

(3) Advanced Refractive Environmental Prediction System (AREPS). AREPS computes and displays a number of TDAs including radar probability of detection and range display, Electronic support Measure (ESM) vulnerability, UHF-VHF communications, surface search radar range display, electromagnetic ray tracing, and simultaneous radar detection and ESM vulnerability. All decision aids are displayed as a function of height, range, and bearing. Detection probability, ESM vulnerability, and communications assessments are based on EM system parameters stored in a user maintained database. Paths containing land features depend on terrain data obtained either from the National Imagery and Mapping Agency's (NIMA) Level 1 Digital Terrain Elevation Data (DTED), or specified from the user's own source.

(4) Target Acquisition Weather Software (TAWS). TAWS predicts the performance of air-to-ground electro-optical weapon and navigation systems. Several types of performance predictions are available: illumination analysis, target acquisition analysis for a single location, and target

acquisition analysis for multiple locations on a regional map. TAWS is most often used by NOAC personnel to obtain infrared (IR) detection ranges for several U.S. Navy systems.

(5) GFMPL. The Geophysics Fleet Mission Program Library (GFMPL) is a collection of atmospheric and oceanographic software applications similar to OAML. It provides meteorological, electromagnetic, oceanographic, hazard avoidance, and acoustic software for fleet air, surface, amphibious, and undersea warfare (USW) operations.

(6) NOAC Yokosuka Produced ASW Products. Products intended for CTF-74/54 or CDS-15 for contain similar core elements, despite being used for very different platforms and purposes. In general, the following environmental analysis concepts provide the basis for NOAC briefs:

(a) Atmospheric Summary.

(b) Oceanographic Environmental Description.

(c) Static Features of Operating Area. (To include bathymetry, sediment type, and historical traffic).

(d) Qualatative Environmental Summary and key points.

(e) Acoustic Analysis.

(f) Non-acoustic Analysis.

CHAPTER 2
Geography

1. East and Southeast Asia Geography. The physical structure of eastern Asia and the adjacent ocean areas have a significant influence on the weather of the region, see figure 2-1. The many meteorological conditions described herein result from air mass trajectories and modifications imposed by the land and water areas over which the air masses travel. A careful study of the topography of eastern Asia and the bathymetry of adjacent water areas is essential to successful forecasting. It is recommended that a current atlas be used in conjunction with the maps reproduced in this manual. Be aware that place names may have ethnic variations depending on the atlas being used.

FIGURE 2-1. EASTERN ASIA

a. Kamchatka and Kuril Islands. The Kamchatka Peninsula extends south-southwestward from the Arctic Circle to approximately 51^{o} N latitude. The Koryak Mountain Range dominates the peninsula, extending the length of Kamchatka. Elevations commonly exceed 8,000 feet (2,440 m) with individual peaks ranging 11,000-16,000 feet (3,355-4,880 m). Forty volcanoes are known to exist on the peninsula and 15-20 are active. Extending southwest from the tip of Kamchatka are the Kuril Islands. Volcanic in nature, more than 100 cones (approximately 40 active) form the island chain. Several of the Kuril Islands are disputed by Japan and Russia.

b. Siberia. Coastal Siberia is mountainous, with the Kolyma and Dzugdzhur ranges extending from the Arctic Circle to 55^{o} N latitude and circling the western Sea of Okhotsk. Elevations range from 3,000 to 7,500 feet (915 m to 2,288 m). Approximately 400 miles (644 km) inland, the Okhotsk-Kolyma Range exceeds 8,000 feet (2,440 m). The Siberian Plateau extends from the Verkhoyansk Range (135^{o} E longitude) to the Ural Mountains (60^{o} E longitude). The eastern region consists of mountain areas, the central region is primarily barren highlands and the western area is generally lowlands. The peaks of the Sikhote Alin Mountain Range, located northeast of Vladivostok, average 3,000-5,000 feet (915-1,525 m). North of Vladivostok lays the open plains of the Ussuri River Valley. The plains average 500 feet (153 m) above sea level and extend 60 miles (97 km) along the coast forming a natural outlet for northerly winds.

c. Japan and the Ryukyu Islands. The Japanese Archipelago is composed of four main islands and a major island chain. Hokkaido is the northern-most island; Honshu is the largest main island; Shikoku is located east of southern Honshu; and Kyushu is the southern-most island. The Ryukyu Island chain extends southwest from Kyushu and forms a 750 mi (1,208 km) arc between Kyushu and the northern most tip of Taiwan. This island chain is a natural boundary between the East China Sea to the west and the Philippine Sea to the east, often referred to as the first island chain. Four-fifths of the country is mountainous, including approximately 165 volcanoes (45 of which are still active). The “Japananese Alps” (Nihon Arupusu), located in central Honshu, are the major mountain chain of the Japanese islands; they average 5,000-12,000 feet (1,525-3,660 m) in elevation. The Alps include Hida, Kiso, and Akaishi mountain ranges. The mountains of Hokkaido constitute the second major chain, averaging 5,000-6,000 feet (1,525-1,830 m). The third chain is on the island of Kyushu; it averages only 5,000 feet (1,525 m) in height.

d. China. China may be divided into six major geographic regions, each of which contains considerable geomorphologic and topographic diversity.

(1) The Northwest. This region consists of two basins, the Dungaree Basin (Jogger Pendi) on the north and the Tarim Basin on the south, divided by the lofty Tien Shan Moutain Range

(Tian Shan). The Tarim Basin contains the vast sandy Takla Makan (Taklimakan Shamo), the driest desert in Asia. Dune ridges in its interior rise to elevations of about 330 ft (100 m). The Turfan Depression (Turpan Pendi), the largest area in China with elevations below sea level, commands the southern entrance of a major pass through the Tien Shan. The Dzungarian Basin, although containing areas of sandy and stony desert, is primarily a region of fertile steppe soil and supports irrigated agriculture.

(2) The Mongolian Borderlands. Located in north central China, this is a plateau region consisting mainly of sandy, stony, or gravelly deserts that grade eastward into steppe lands with fertile soils. This region of flat-to-rolling plains is partitioned by several barren flat-topped mountain ranges. Along its eastern border is the higher, forested Greater Khingan Range (Da Hinggan Ling).

(3) The Northeast. Comprising all of Manchuria east of the Greater Khingan Range, the Northeast region incorporates the Manchurian Plain (Dongbei Pingyuan) and its bordering uplands. The plain has extensive tracts of productive soils. The uplands are hilly to mountainous, with numerous broad valleys and gentle slopes. The Liaodong Peninsula, extending to the south, is noteworthy for its good natural harbors.

(4) North China. This region lies between the Mongolian Borderlands to the north and the Yangtze River Basin to the south and consists of several distinct topographic types. The Loess Plateau in the northwest is formed by the accumulation of fine windblown silt (loess). The loosely packed loess is readily subject to erosion and sunken roads, vertical-walled valleys and numerous gullies transect the plateau’s surface. The region is extensively terraced and cultivated. The North China Plain, the largest flat lowland area in China, consists of fertile soil composed of loess. Located to the east, the Shandong Highlands on the Shandong Peninsula consist of two distinct areas of mountains flanked by rolling hills. The rocky coast of the peninsula provides good natural harbors. To the southwest are the Central Mountains, which constitute a formidable barrier to north-south airflow.

(5) South China. This region embraces the Yangtze Valley and the topographically diverse regions to the south. The Yangtze Valley consists of a series of basins with fertile alluvial soil. These lowlands are crisscrossed with waterways, both natural and artificial, and dotted with lakes. The Sichuan

Basin, located to the west, is enclosed by rugged mountain spurs of the Central Highlands and constitutes a relatively isolated area of hilly terrain. The area is known for its intensive terraced farming. The highlands of South China extend from the Tibetan Plateau east to the sea. In the west the deeply eroded Yunnan-Guizhou Plateau is bordered by a series of mountain ranges separated by deep, steep-walled gorges. One of the world's most scenic landscapes is found in eastern Guizhou, where tall limestone pinnacles and pillar-like peaks dominate the terrain. To the east are the largely deforested and severely eroded Nan Ling hills, and along the coast are the rugged Southeastern Highlands, where bays with numerous offshore islands provide good natural harbors. Lying south of the Nan Ling hills is the Xi Jiang Basin, predominantly a hilly area with infertile soils. However, the numerous streams of this region produce narrow fertile flat-floored alluvial valleys. The broad delta plain of the Zhu Jiang (Pearl River) is commonly called the Canton Delta.

(6) The Tibetan Plateau. Occupying the remote southwestern extremity of China is the high, mountain-rimmed, plateau of Tibet. The world's highest plateau region, it has an average elevation of about 14,800 ft (about 4510 m) above sea level. Bordering ranges include the Himalaya on the south, the Pamirs and Karakorum Range on the west, and the Kunlun Shan and Qilian Shan on the north. The surface of the plateau is dotted with salt lakes and marshes and is crossed by several mountain ranges. It also contains the headwaters of many major southern and eastern Asian rivers, including the Indus, Ganges, Brahmaputra, Mekong, Yangtze (Chang Jiang), and Huang He (Huang Ho or Yellow River). The landscape is bleak, barren, and rock strewn.

(7) The coastal areas of eastern mainland China are characterized by extensive low-lying mountain ranges with elevations commonly below 3,000 feet (915 m). The Nangnim Range (southwest of Vladivostok) continues into eastern Manchuria and northern Korea with elevations of 8,000 feet (2,440 m). The Manchurian Plain extends from the foothills of the Nangnim to the Greater Khingan Range on the edge of the western Gobi Desert. The extreme western extent of the Himalayan Mountains dominates central and western China.

e. Mongolia. Mongolia lies in central Asia with Russia to the north and China to the south. The Gobi desert, in the southeast region, supports no vegetation and is sparsely populated. Funneling between the ranges of western Mongolia and

Manchuria can cause strong winds over the desert area. Airborne sand is routinely observed in the Yellow Sea and Sea of Japan. The northern extension of the Alta Mountains dominates the terrain of northwestern Mongolia.

f. North and South Korea. The Korean Peninsula extends 600 miles (966 km) from 44^{o} N latitude to 33^{o} N latitude and has a total area, including offshore islands, of 75,250 sq mi (194,899 sq km). The peninsula extends to within 120 miles (193 km) of Honshu and the Shantung Peninsula of China. North Korea measures about 445 miles (716 km) from northeast to southwest and is approximately 225 miles (362 km) wide. It is bordered by China to the north and Russia to the extreme east. About eighty percent of North Korea is mountainous. The Kaema Plateau, average elevation 3,280 feet (1,000 m), bisects the country. The Hamgyong Mountains form the eastern edge of the plateau and rise to over 8,200 feet (2,501 m). The eastern lowlands are a very narrow strip of land between the plateau and the coast. The western lowlands are much wider. South Korea is also quite mountainous (approximately seventy percent of the total landmass.) The main range, the Taebaek Mountains roughly parallels the east coast. Four other major ranges (Charyong, Kwangju, Sobaek and Noryong) extend perpendicularly to the Taebaek Mountains. Most of the lowlands are located in the western Peninsula.

g. Taiwan. The Republic of China today consists of the island of Taiwan located 100 mi (161 km) off the Asian mainland in the Pacific, two offshore islands, Kinmen (Quemoy) and Matsu, and the nearby islets of the Pescadores chain. The Republic of China is slightly larger than the combined areas of Massachusetts and Connecticut. Taiwan is divided by a central mountain range that runs from north to south, rising sharply on the east coast and descending gradually to a broad western plain, where cultivation is concentrated. The mountains have peaks of 12,743 feet (3,887m) and 13,114 feet (4,000 m) in the northern and central regions of the island.

CHAPTER 3
Oceanography

1. Oceanography. The oceanic regions of the western North Pacific include both marginal seas and deep ocean areas. Significant differences in physical properties exist between these ocean regimes that impact temperature profiles, salinity and bottom characteristics. These differences determine the region’s sound speed profile, which affect acoustic propagation characteristics. Critical features and effects of the bottom topography, ocean fronts and eddies and ocean currents will be briefly covered.

a. Bottom Topography.

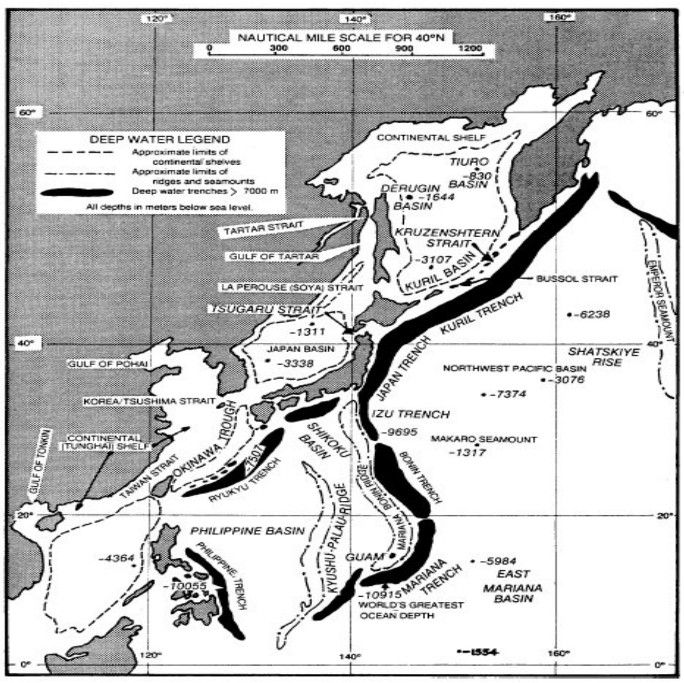

FIGURE 3-1. BOTTOM TOPOGRAPHY OF THE WESTERN NORTH PACIFIC

(1) Western North Pacific. The majority of ocean area discussed here is comprised of open ocean, deep basins and trenches, see figure 3-1. A fundamental characteristic of the Pacific Basin is the semi-continuous belt of trenches. The Kuril Trench 27,880 ft (8,503 m) parallels the Kuril Island chain, with maximum depths found between Hokkaido and the central Kuril Islands. The Japan Trench 35,440 ft (10,809 m) is located just to the east of northern Honshu, continuing south-southeastward to near 30° North. The Bonin Trench 28,405 ft

(8,664 m) is found along the eastern edge of the Bonin Island chain. The Mariana Trench extends from the base of the Bonin Trench to approximately 10° North on the eastern periphery of the Mariana-Bonin ridge. The Challenger Deep, at 35,800 ft (10,919 m), is the deepest trench in the world. The Yap-Palau Trenches extend from the base of the Mariana-Bonin Ridge to approximately 7° North along the southeastern periphery of the Kyushu-Palau Ridge. West of these deep trenches, the bottom slopes are quite extreme, rising rapidly to the relatively shallow continental shelf of Japan, the Kuril Islands and the Bonin Islands.

(2) Sea of Okhotsk. The Sea of Okhotsk is one of the marginal seas of the Pacific, situated in the northwestern part of the ocean. It is separated from the Pacific by the Kuril Island chain and the Kamchatka Peninsula. The Kuril Straits connect the Sea of Okhotsk with the Pacific Ocean and the Tartar and Soya Straits with the Sea of Japan. The Sea of Okhotsk lies within the transition zone from the continent to the floor of the Pacific Ocean proper. There are three categories of bottom topography: continental and island shelves, the central shelf and the southern deep-water basin. The shelf area constitutes more than 40% of the entire sea area. Bottom composition is mainly sand and silt. The central shelf consists of a series of ridges and troughs with depths ranging from 656 ft (200 m) to 5,740 ft (1,751 m). The Kuril Basin runs along the inner edge of the Kuril Islands with a maximum depth of 10,253 ft (3,107 m). The basin is surrounded on all sides by slopes as steep as 15-20°. Sedimentary cover over the near shore summits and slopes of marine rises is mainly pebbly gravel and sand. The majority of the basin is covered in bands of silts, clay and ooze.

(3) Sea of Japan. The Sea of Japan is a marginal sea of the western North Pacific. The basin is bordered on the east by the Japanese Islands and on the west by the Korean and Siberian coasts. Openings to the Pacific and other seas are through the Tsushima (Korean) Strait to the south, Tsugaru Strait between the islands of Hokkaido and Honshu, the Soya (La Perouse) Strait between Hokkaido and Sakhalin Island, and the Tartar Strait between Sakhalin Island and the Asian mainland. The central Sea of Japan is dominated by the Japan Basin and Japan Abyssal Plain. The Tartar Trough extends southward from between Siberia and Sakhalin Island to the Japan Basin. The most prominent individual topographical feature in the Sea of Japan is the Yamato Rise, which is divided into the Kita-Yamato Ridge and the Yamato Ridge by the Yamato Trough. Most of the continental shelf area is very narrow except in the extreme northern portion

near Hokkaido and Sakhalin Island. Steep slopes of over 30° bound the ridge and trough features. The Tsushima/Korea Strait is oriented northeast-southwest between the southern Korean coast and the southwestern coast of Honshu. The strait is comprised of East and West channels which are located on either side of Tsushima Island. The bottom topography of the strait is a continuation of the continental shelf of the East China Sea. A relatively flat bottom dominates the strait. The major features include: Tsushima Island located approximately in the middle of the straits, the irregular coastlines of Korea to the north and Japan to the south, and a depression centered off the northwest coast of Tsushima Island in the West Channel.

(4) Yellow Sea. The Yellow Sea is bounded by China to the west and north, North Korea to the northeast, South Korea to the east, and the East China Sea to the south-southeast. The geographic configuration allows for division into three segments: the Gulf of Bohai to the northwest, Korea Bay to the northeast, and the Yellow Sea. For purposes of this handbook the Yellow Sea and Korea Bay will be called the Yellow Sea proper. The Yellow Sea proper and Gulf of Bohai form a partly enclosed, wide, flat, shallow marine embayment. The entire area is part of the continental shelf with depths averaging from 197-252 ft (60-77 m). Numerous sand ridges and channels run perpendicular to the coast. Strong tidal currents and numerous rivers carry suspended particles into the Sea which are then sorted by the currents. The bottom of the central basin and the Chinese side of the Bohai Bay are composed mainly of muddy silt.

(5) East China Sea. The East China Sea (ECS) bathymetry is divided into two contrasting areas: the continental shelf which makes up the shallow water area and the Okinawa Trough which constitutes the deep water area. The shelf area is relatively narrow and elongated. Widths vary from 170 NM near Taiwan to 450 NM near the northern boundary (33° North). There are a few scattered islands near the outer edge of the shelf. Outflow from the Yangtze (Yellow or Changjiang) River is the primary origin of shelf material. The general bottom composition consists of 85 NM wide belt of mud along the shore followed by a broader zone of fine-grained sediments that change to sand at the outer shelf area. The Okinawa Trough borders the continental shelf with the western side defining the continental slope. The trough extends from Taiwan to Kyushu along the inner Ryukyu Island arc.

(6) Philippine Sea. The limits of the Philippine Sea are defined by the Philippine islands of Luzon, Samar and

Mindanao on the southwest; the island of Palau, Yap, and Ulithi on the southeast; the Mariana Islands on the east; the Bonin and Volcano Islands on the northeast; the Japanese islands of Honshu, Shikoku and Kyushu on the north; the Ryukyu Islands on the northwest and Taiwan on the west. The Philippine Sea is an abyssal zone with depths generally greater than 6,500 ft (2,000 m). The bottom topography consists of deep trenches over 19,600 ft (5,978 m) in depth, belts of seamounts, and deep basins. The abyssal deep basin is separated into east and west basins by the Kyushu-Palau Ridge. The bottom sediments are pelagic red clays and oozes with volcanic material along the island arcs.

(7) South China Sea. The South China Sea (SCS) is bordered on the north and west by the Asian mainland, the southern limit of the Gulf of Thailand and the Malay Peninsula on the southwest and the south, the Philippine Islands to the east and Taiwan northeast. The China Sea Basin, located in the north central portion of the sea, dominates the majority of the SCS with a maximum depth of 17,400 ft (5,307 m). The central portion of the SCS is an abyssal plain. Large reef-studded shoal areas occur within the basin in the southern area. The bottom sediment is predominately made up of clay with areas of gravel, sand, and silt in the vicinity of coastal areas and along the continental shelf. Clay is the main sedimentary feature in the deeper portions of the basin. Volcanic ash is found in layers throughout the basin.

b. General Oceanographic/Acoustic Conditions. A complete review of ocean thermal and acoustic properties and resulting sound propagation characteristics is beyond the scope of this handbook. General oceanic and acoustic conditions for the Western Pacific and Indian Ocean will be discussed.

(1) Western North Pacific. The change in thermal properties across the Kuroshio Extension and Oyashio Currents is one of the largest found in the open oceans. The thermal variation is most pronounced below the seasonal surface layer and above the deeper stable waters. The gross structure of thermal features across this boundary zone can be detected in satellite infrared imagery during the seasons when the surface has not been heated sufficiently to mask thermal contrasts. The depth of the Sound Channel Axis (SCA) rises rapidly northward across the Perturbed Area, being very near the surface poleward of 42° North during the warmer months. This is due to the surface warming of the waters. During the colder months, the sound speed minimum reaches the surface and the sound channel will disappear north of 42° North. Sound energy is then

transmitted via half-channel propagation. South of the Kuroshio Extension a deep sound channel exists between 4,200-4,750 ft (1,281-1,450 m) in the western area and rises about 3,700-4,000 ft (1,150-1,450 m) near 160° East. Generally, the highest sea state is found during the winter as strong mid-latitude weather systems migrate through the area. Sea ice may be found during the late fall through early spring along the seaward areas of Kamchatka, the Kuril islands and Hokkaido.

(2) Sea of Okhotsk. The sound channel axis is located at the surface during the colder months during which half-channel conditions prevail. During the warmer months surface heating results in a near surface sound speed maximum and a shallow SCA. The Sea of Okhotsk begins to freeze in coastal locations during November and reach its peak ice coverage during March. It is nearly ice-free by June. Coastal ice will form first in the northeastern and northwestern extremes then along the remainder of the northern and western boundaries and the Kamchatka Peninsula. The ice edge then advances toward the center of the basin reaching maximum coverage by March. The sea surface will not completely freeze over except during an unusually cold year.

(3) Sea of Japan. Large seasonal changes occur in the thermal properties of the near-surface waters. During late summer and autumn, a convectively mixed two-layered thermal structure prevails. As the cold air flows over the surface, removing heat from the near surface-layer, the seasonal mixed layer and thermocline are destroyed resulting in a surface-to-bottom homogeneity in the cold sector. The Sea of Japan is divided into two sectors based on currents: the warm sector on the Japanese side and a colder sector on the Korean and Siberian side. In the warm sector a deep thermocline persists throughout the year. The winter cooling is not sufficient to completely remove the heat and destroy the thermocline. Full channel conditions exist throughout the Sea of Japan during the summer and autumn, and year-round in the warm sector. During winter and spring half-channel conditions are found in the cold sector. Highly variable conditions will be found in the vicinity of the frontal zone. A general decrease in depth of the sound channel axis occurs from east to west and south to north. The deepest axis is found in the Korean Strait 1,640-2,000 ft (500-600 m) in association with the Tsushima Current. Near the central Japan Islands, in the area of the Tsushima Current, the axis is found near 1,300-3,000 ft (397-915 m). Values off the Siberia coast range from surface to 650 ft (0-198 m). Sea ice begins to form in the Tartar Straits around mid-November and in the northern

Sea of Japan by mid-February. Along the northern coast of Korea sea ice is limited to coastal bays and harbors.

(4) Yellow Sea. The circulation of the Yellow Sea is strongly influenced by regional atmospheric forcing and bottom topography. The major ocean currents play only a limited role in the circulation. The atmospheric monsoon regime that prevails over the area provides cyclic seasonal changes that dominate the region's oceanographic processes. Atmospheric forcing occurs in two modes. During winter, cooling and mixing occur due to strong, cold, dry northerly winds; in summer extensive precipitation, river run-off and solar heating produce a well-stratified water column with a warm, low-salinity surface layer. Seasonal conditions are further agitated by strong winter cold outbreaks and occasional summer typhoons. The Yellow River is the major source of fresh water influx into the southwest region of the Bohai. Other sources include the Luanhe and Liaohe Rivers entering the western and northern Pohai and the Yalu, Han and lesser rivers of Korea. Two regions of upwelling are found in the Yellow Sea: the eastern region of the Shandong Peninsula and off the southern tip of Liaodong Peninsula. Water temperatures off the tips of these two peninsulas are found to be 3-5° C lower than surrounding areas during May and August. Cold water from upwelling extends seaward 15-30 NM off the Shandong Peninsula, while the Liaodong Peninsula upwelling is limited to about 10 NM off the coast. Sea ice is observed as far south as 36° North along the Korean coast and south of the Shangdong Peninsula. The major concentration of sea ice (0.1-0.4 octaves coverage) is limited to the western and northern Gulf of Bohai and eastern Korea Bay.

(5) East China Sea. The East China Sea is influenced by the same atmospheric forcing as discussed in the Yellow Sea. The conditions within the East China Sea are influenced on the western side by the discharge of the Yangtze River and on the eastern side by the Kuroshio Current, its branches and extensions, which mix with coastal waters. Coastal upwelling occurs off the Zhejiang Peninsula (Chinese coast north of Taiwan to near 30° North), mainly as a summer phenomena and is directly related to the intensity of the Southwest Monsoon surface wind. Tidal currents show a wide variety of ranges, especially in the vicinity of islands. Maximum heights of 2-3 feet (0.5-2.8 m) occur around the Ryukyu Islands with tidal current speeds of 2-3 knots. Tidal ranges of 15-20 ft (4.5-6 m) occur around Taiwan, and of over 30 ft (9 m) in the mainland Hangchow Bay southwest of Shanghai.

(6) Philippine Sea. Several major currents affect operations within the Philippine Sea: the North Equatorial Current, the Equatorial Countercurrent, the Kuroshio Countercurrent, the Subtropical Countercurrent and the Kuroshio Current. The correlation between oceanic fronts and large bottom slopes are a common feature within the Philippine Sea. These conditions present special problems to ASW operations as grid point or single point data do not account for the loss or redirection of bottom bounce propagation. The Sound Channel Access (SCA) is quite deep throughout the area with a maximum depth of over 4,900 ft (1,495 m) year round near 30° North, 135° East. The SCA rises to about 2,300-2,600 ft (702-793 m) near the western and northern boundaries except during winter when the channel depths are about 2,900-3,200 ft (886-976 m). Water depths are a limiting factor not only in coastal areas but over the lesser depths along the Ryukyu and Mariana/Bonin Island Chains.

(7) South China Sea. The temperature structure of the water column between the surface and 650 ft (198 m) is influenced by the seasonal changes that take place over the region. During the winter season northeast winds dominate the South China Sea deflecting surface water toward the Vietnamese coast. The mixed layer above the sharp thermocline becomes deeper near the coast as surface water is deflected and reaches depths of 500 ft (153 m). The summer southwest monsoon winds develop strong southerly currents that extend all along the coast and through the South China Sea. The thermocline rises and pronounced upwelling takes place near the coast with the maximum upwelling occurring off the coast of south-central Vietnam.

c. Ocean Fronts and Currents. Refer to figure 3-2 for the major Northwest Pacific ocean fronts and associated currents.

(1) North Equatorial Current (Pacific). The beginning of the North Equatorial current can be found off the coast of Central America, traversing the Pacific in an east-west set analogous to the Trade Winds. The North Equatorial Current is an integral portion of the transport system to return northern waters to southern regions. Characteristic speeds of this current are 0.5-2 knots.

(2) Equatorial Countercurrent. The Equatorial Countercurrent is a west to east flowing current related to the region of low winds speeds located between the northeast and southwest trades. It has its origins along the coast of the

Philippines, moving eastward to the American coast. This current, present year round, lies just to the north of the Equator in winter and migrates northward with the shifting weather patterns in the summer. Speeds of up to 2 knots have been observed at the surface.

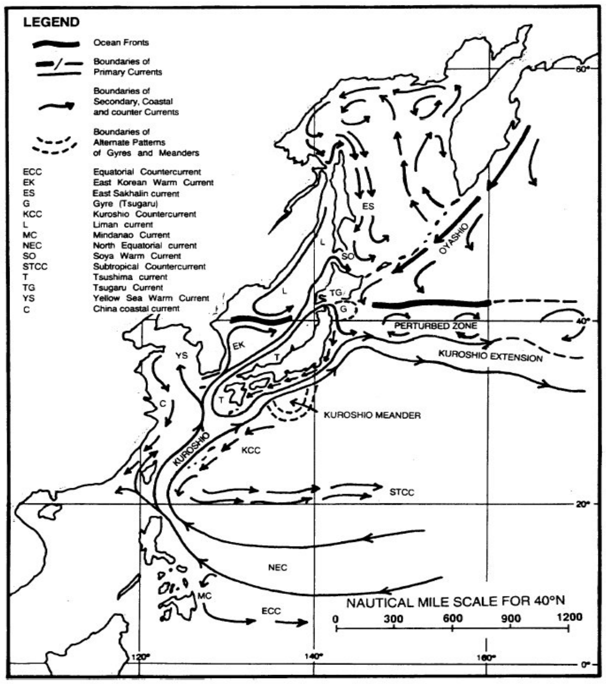

FIGURE 3-2. NORTHWEST PACIFIC OCEAN FRONTS AND CURRENTS

(3) Kuroshio Current. The Kuroshio (translated as Black Stream) Current is the dominant ocean current of the western Pacific and resembles the Gulf Stream of the Atlantic. The Kuroshio begins east of northern Luzon in the Philippine Sea before flowing into the ECS northeast of Taiwan. Then the Kuroshio follows the Okinawa Trough between the continental shelf and the Ryukyu Ridge. The current then splits into two parts, with the major portion flowing east to south of Shikoku then northward along the southern coast of Japan. During the northeastward set, the current accelerates to 2-5 kt with maximum speed occurring between 132° East and 137° East. While flowing northward, the current parallels the 3,000-9,000 ft contour. A minor branch flows northward through the Korean Strait as the Tsushima current.

(4) Kuroshio/Subtropical Countercurrent. The Kuroshio Countercurrent (KCC) flows north to south along the eastern edge of the Kuroshio transporting large amounts of water southward. The development or continuity of the countercurrent depends on

the displacement north of the Kuroshio. It sometimes consists of only sporadic portions along the Kuroshio. The Subtropical Countercurrent (STCC) connects with the Kuroshio Countercurrent. The STCC will normally be found between 20° North and 24° North. Found throughout all seasons, it is usually most developed during winter.

(5) Kuroshio Extension. The Kuroshio Extension is a continuation of the Kuroshio Current extending eastward from coastal Japan near 140° East to 160° East and meandering between 35° and 38° North. This meandering path forms a transition zone between the cold waters to the north and the warm subtropical waters to the south.

(6) Oyashio Current. The Oyashio Current originates in the Bering Sea and flows southwest off Kamchatka Peninsula and the Kuril Islands, entraining water from the Sea of Okhotsk. The Oyashio current then flows along the eastern coasts of Hokkaido and Honshu before curving eastward to parallel the Kuroshio Current before gradually merging with the Kuroshio Extension beyond 160° East.

(a) Perturbed Area (Northwest Pacific). The Perturbed Area is the boundary between the warm Kuroshio Extension Current and the cold Oyashio Current to the north. The area is roughly 200-300 NM wide and extends well past 160° east. This boundary area is typically composed of a series of eddies and meanders. Warm eddies, 80 NM in diameter or larger, tend to be stationary and short-lived, while those at least 150 NM in diameter will have a lifetime of at least one year. These large eddies are formed when large northward meanders of the Kuroshio Current break off from the main current just off the eastern coast of Honshu.

(7) East Sakhalin Current. The East Sakhalin Current is part of the cyclonic circulation (Okhotsk Gyre) flow that dominates the Sea of Okhotsk. This oceanic circulation is connected with the atmospheric circulation above the Sea of Okhotsk and the western Pacific.The East Sakhalin Current is a narrow near shore counterclockwise current. It begins in the southeast basin near Kamchatka where water is forced from the Pacific through the northern Kuril Island Straits.

(8) Soya Current. The Soya Current flows through the LaPerouse (Soya) Strait that separates the islands of Hokkaido and Sakhalin. The complex topography and extended shelf (depths

of less than 650 ft results in large fluctuations in volume, speed and path of the warm current flowing into the strait. The Sea of Japan Oceanic Polar Front (previously discussed) and cold waters to the north and west also hinder flow into the Soya Current. At its strongest, the Soya Current will occupy only the southern portion of the strait with cold water in the northern portion. The resulting oceanic front separating the two water masses is quite sharp with current speeds of 1-2 kts within the warm water. After exiting the strait, the Soya Current turns south along the coast of Hokkaido. This portion is strongest during late summer and will disappear at the surface during the winter.

(9) Sea of Japan Oceanic Polar Front. The Sea of Japan is divided into two sectors based on currents: the warm sector on the Japanese side and a colder sector on the Korean and Siberian side. The warm sector is comprised of the Tsushima current and its extension, the warm East Korea, Tsugaru and Soya currents. The cold sector is comprised of the Liman, North Korean and Mid-Japan Sea Cold currents, see figure 3-3. A persistent, year-round oceanic “Polar Front” along 38-40° North separates the two sectors. Eddy circulation patterns exist in the frontal zone with accompanying large horizontal variations of physical properties.

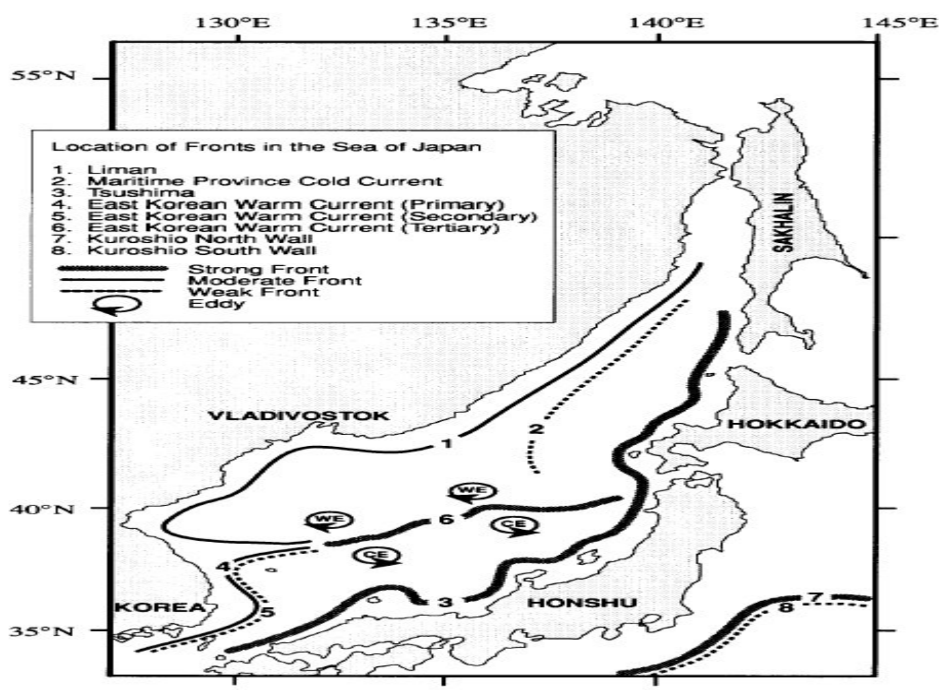

FIGURE 3-3. SEA OF JAPAN FRONTS AND CURRENTS

(10) Tsugaru Current. The Tsugaru Current is an extension of the Tsushima Current. Due to island topography and shallow sill depth (425 ft/130 m), the current through the channel forms a core approximately 11 NM wide. On either side of the core are eddies which appear to be trapped due to topographical configuration. Maximum current speeds reach 4.5-5.5 kts during the spring tidal phase of summer and winter. The Tsugaru Current extension into the Pacific displays distinct variations in patterns between periods of weak and strong transport. An extensive anticyclonic gyre is observed during strong outflow mainly in the summer and fall seasons. During weak outflow, mainly in the winter and spring, a coastal pattern is observed.

(11) Liman, North Korea, Mid-Japan Sea Cold Currents. The cold sector of the Sea of Japan is comprised of three cold currents: the Liman current which flows along the Siberian coast, the North Korea current from Vladivostok to the central east Korean coast, and the Mid-Japan Sea Cold Current which flows eastward into the central portion of the Sea of Japan.

(12) Tsushima Current. The Tsushima Current is a warm current that branches off from the left side of the Kuroshio, flowing first through the eastern ECS and then entering the Sea of Japan through the Tsushima (Korean) Strait. The Tsushima Current is the source of all the warm currents within the Sea of Japan. The Tsugaru and Soya Warm Currents are the northern extension of the Tsushima as it flows out of the Sea of Japan through the Tsugaru and Soya Straits, respectively. The East Korea Warm and Yellow Sea Currents are western extensions of the Tsushima Current

(13) East Korea Current. The East Korea Current diverges from the Tsushima Current upon entering the Sea of Japan. It then flows northward along the Korean coast as far north as Yongil Bay, turning southeast to rejoin the Tsushima Current near 39° North.

(14) Yellow Sea Current. The Yellow Sea Current branches from the Tsushima Current near western Kyushu and flows northward into the middle of the Yellow Sea. The speed of the current is less than 0.5 kts. It develops in spring and summer and decays in the fall and winter.

(15) China Coastal Current. Completing the gyre of the Yellow Sea is the China Coastal Current which flows southward along the coast. Although present year round, the current

strengthens during the winter as it is accelerated by the strong, persistent Northeast Monsoon.

(16) South China Sea Currents. The monsoon winds control the surface currents flowing into the SCS. In the winter, the surface flow is from the north through the Taiwan Straits and Bashi Channel, and from the east through the Balabac Strait. The outgoing flow is mainly through the south into the Java and Flores Seas through the Karimata and Gasper Straits and a little to the west through the Malacca Straits. During summer months the surface flow will reverse moving from the Flores/Java Seas through the Karimata and Gasper Straits and entering the SCS between Malaysia and Borneo. The flow is generally to the northeast.

CHAPTER 4
Climatology

1. Atmospheric Climatolgy.

a. Mid-Latitude Climate Systems of East Asia. The climate of East Asia is divided into six seasons. The winter months (November through March) are predominantly driven by jet streams coupling with mid-latitude weather systems. As Asia transitions into the summer months, the western periphery of the Western Pacific Subtropical Ridge begins to advect warm, moist maritime tropical air over the region, producing the rainy season. During the summer months, in southern Japan, the Western Pacific Subtropical Ridge produces hot, humid days with late afternoon thunderstorms. Tropical cyclone season in East Asia runs from May through November and is considered the predominant climatological element for the summer months.

b. Air Masses. The air masses that influence mid-latitude regions are Continental Polar (cP), Maritime Polar (mP), Maritime Tropical (mT), Continental Tropical (cT), and Maritime Equatorial (mE), see figure 4-1.

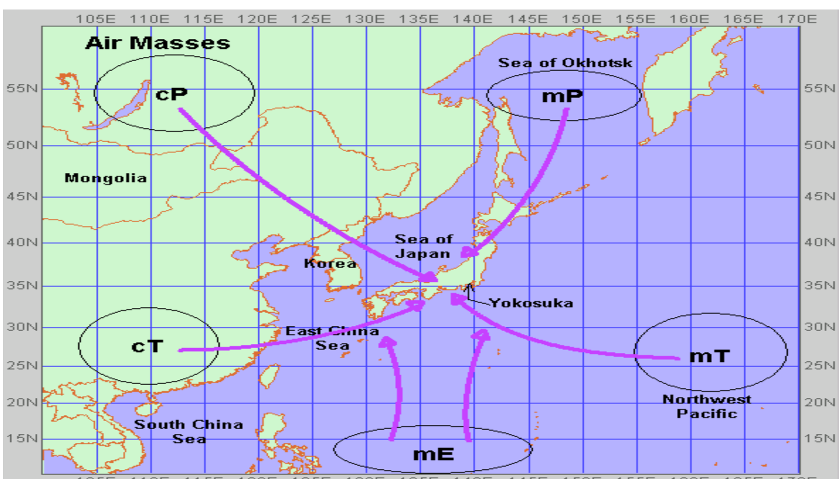

FIGURE 4-1. AIRMASSES THAT INFLUENCE JAPAN

(1) Continental polar (cP) air is the most dominant air mass during the winter months in the mid-latitudes. In the winter, as portions of Siberia become frozen and form a homogeneous environment, the Siberian High is formed and generates a strong cP air mass. As this air mass moves out of the source region towards the south and east, the areas that it passes experience cold and dry weather. As the cP air mass

migrates southeastward, heating from below causes the boundary layer of the air mass to become unstable and as it moves over water, it gains moisture content (increasing water vapor content). As the dry, cold air moves out over the warmer waters of the Yellow and East China Seas, the air mass is quickly modified as it picks up moisture and becomes mP. When the outbreak is strong enough, it will produce snow over the Sasebo area. When the air mass approaches a mountain range such as the Japanese Alps, orographic lifting occurs causing heavy snow fall over the west side of mountain ranges. A cP air mass can be warmed as much as 25°F by the time it reaches the Sea of Japan. Cloud tops do not normally extend over 5,000 or 6,000 feet. However, over the warmer ocean currents, much greater thickness can be attained. As a rule, the colder the air, the greater the effect the heating from below has upon the air mass with more extensive cloud build-ups. The cP air mass dries and warms adiabatically as it descends on the leeside of the mountains. This results in clear skies and unrestricted visibility over the Kanto plain. As modified cP air continues southward across the warm Kuroshio Current south of Japan, further warming takes place and is associated with the addition of moisture in the air. Cloud decks of stratus, stratocumulus and cumulus frequently result with cumulus tops often extending up to 20,000 feet. During spring and autumn, migratory highs moving across Asia produce a variety of outbreaks of cP air masses. These outbreaks can cause considerally different weather based on the origin of the high. The outbreak from China is usually a warmer and deeper system with anticyclonic circulations reaching considerable heights and covering larger areas.

(2) Maritime Polar (mP) air is relatively cold and moist, most often located in the Sea of Okhotsk. From late spring to early summer, the sea surface temperature (SST) over the central Sea of Okhotsk remains cooler than the surroundings. This develops a semi-permanent high over the Sea of Okhotsk and causes formation of a mP air mass. This mP air often expands to the southwest and interacts with the western edge of a maritime tropical (mT) air mass from the western Pacific Ocean, forming a quasi-stationary front across Japan oriented southwest to northeast. This frontal boundary is called the Bai-u boundary or Bai-u front and brings the late spring/early summer rainy season to Japan. Outbreaks of mP air from China occur infrequently in late spring, summer and early fall. When it does occur, migratory Highs move eastward from the Lake Baikal region across the Sea of Okhotsk, producing a northeast wind flow over the Kanto plain. Because of the long over-water trajectory and the stagnation of the air in the Sea of Okhotsk,

this air mass is maritime modified cP air but is often referred to as maritime polar. The Oyashio Current plays a major role with the modification of air as it flows southward over the cold water. The air will be warmer than the underlying ocean, and as a result, the air mass acquires stable characteristics in the lower levels, producing an extensive stratus and stratocumulus cloud layer over the Kanto Plain. During the Bai-u spring rainy season, widespread precipitation will occur when the polar front exists over the area.

(3) Maritime Tropical (mT) is warm and moist air. As the progression of the sun zenith goes higher in the northern hemisphere and the season transitions from spring to summer, the high-pressure belt (Western Pacific Subtropical Ridge) in the mid-latitudes correspondingly moves north. This is also the source region for formation of mT air masses. Maritime Tropical air originates in the subequatorial regions of the Pacific and is advected northward from the south and southeast by the subtropical ridge. Maritime Tropical air is warm, moist, and conditionally unstable. This implies that day-time heating can easily develop towering cumulus and cumulonimbus clouds. In fact, the presence of air-mass thunderstorms and sudden showers is not unusual with mT air. This often affects Kyushu by bringing warm, moist mT air, creating moderate to heavy rain and occasional embedded thunderstorms. However, when a strong mT air mass influences Japan, all low pressure systems, or frontal boundaries approaching from the west are blocked. This often causes a hot spell across the Kanto plain. The western edge of the Pacific subtropical high pressure provides the source region for mT air affecting Japan and influences weather across the Japanese Islands during the southwest monsoon. Maritime Tropical air flows clockwise around the southern portion of the western Pacific subtropical ridge turning northward between Guam and the Philippines, then advecting towards Japan. This air is conditionally unstable, with the lesser effects of subsidence on the western side of the subtropical ridge also acting to increase the instability. Over the northern Kanto Plain, the instability is further enhanced by orographic lifting along the eastern slopes of the Japan Alps, producing daily thunderstorms and rain showers. Maximum convective activity normally occurs during the late afternoon and early evening hours after maximum heating of the day. Nocturnal and early morning thunderstorms in the mountains are not uncommon, with the cumulus clouds dissipating rapidly several hours after sunrise. As the mT air continues to flow northward, it interacts with the cold waters of the Oyashio Current, producing extensive fog banks along the coast of northern Honshu, Hokkaido, and Sea of Okhotsk.

(4) Continental Tropical (cT) is warm, dry air. The cT air mass is developed over the continental region south of the Yangtze River in China. This is a favorable area for high pressure to remain after being separated from the Siberian High. This cT air mass is basically unstable, but it is also very dry. Thus, it would be very rare to see cloud development and precipitation from this air mass. When this cT air moves over Japan with a migratory high-pressure system, hot and dry weather dominates across the Kanto plain. Since it is very hard to determine the exact source region of this air, cT air mass is sometimes classified as a modified cP air mass from Siberia or a modified mT air mass from the North Pacific.

(5) Maritime Equatorial (mE) is very hot and moist air, formed in the deep tropics, between 10°S and 10°N, as the Inter-Tropical Convergence Zone migrates north during the summer season. During the height of the summer, when the western Pacific subtropical ridge is at its strongest, mE air is occasionally advected northward, influencing the weather pattern over Japan. This very warm and moist air mass can bring heavy rain showers over Japan.

2. Cold Surges in Japan and Korea. Cold surges in Japan and Korea occur during December and January, peaking in January. Due to the frequency of Siberian High formation (about 5 to 7 days), migration pattern of cP air mass, and its moving speed, Kanto plain experiences an average of four days of warm temperatures followed by three days of cold winter weather. During the mid-winter, this cP air mass may expand as far south as the northern Philippines.

3. Mid-latitude Cyclones that Affect Japan. Mid-latitude or extra-tropical storm systems continually develop, dissipate and regenerate in the Northern Hemisphere. Mid-latitude storms which effect Japan develop on the other side of the world across the Atlantic Ocean, where they are carried by the jet streams into our Area of Responsibility (AOR) in two general categories as they approach Asia: mid-latitude storms which move northeastward through Iceland, into the Barents Sea, then southeastward through Asia, and mid-latitude storms which come from the Mediterranean Sea. The Icelandic storm tracks, or northern tracks, culminate near Mongolia and Siberia, with the exception of the Siberian Storm Track, defined as those storms that move through Iceland and transit northward over Franz Josef Land and Spitsbergen Island by a sharp amplitude long-wave ridge, then drop southward toward the Sea of Japan. The storm

tracks originating from the Mediterranean, or southern tracks, become dynamic by-products of the numerous splits in the storm track impulses that move across Asia. These general storm tracks eventually transform into East Asian storm storm tracks. Forecasters classify six types of East Asian cyclones according to the areas of origin and their trajectories, see figure 4-2, generally categorized into northern and southern lows:

a. The Northern Lows. The Northern Lows will normally generate/regenerate in northern China or southern Russia. The lows will then depart their source regions tracking eastward to the northern Sea of Japan/Sakhalin Island before reaching the western Pacific. These low-pressure systems are formed by movement of upper-level short wave troughs through low-pressure source regions. These systems are enhanced by down slope adiabatic warming as they traverse from their mountainous regions toward the coast. With the northern lows tracking into the Sea of Japan, once the low reaches 136°E, the winds at Yokosuka will shift to strong to gusty southwesterlies (small craft strength) and will reach maximum velocity as the low reaches 140 degrees east.

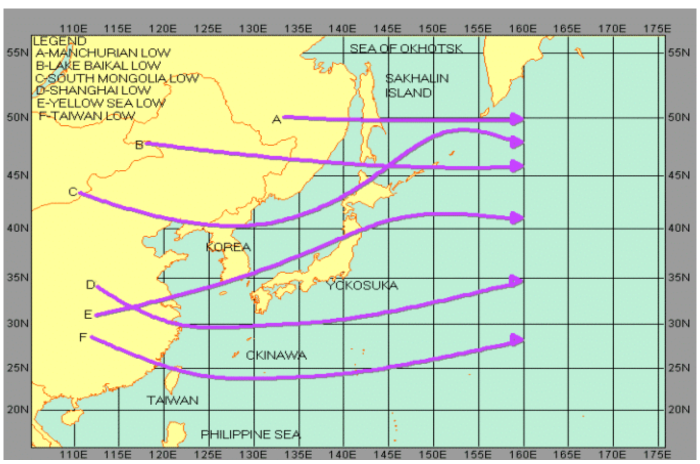

FIGURE 4-2. CHARACTERIZATION OF THE SIX CYCLONES

(1) Manchurian Low. The Manchurian Low, see figure 4-3, develops over the northern border of Manchuria, moving eastward over central Sakhalin Island before exiting into the Sea of Okhotsk. This system occurs primarily during the autumn and spring. Average speed of this system is 20 knots. The Manchurian Low generally has very little weather associated with it since the source region of Siberia offers little moisture until reaching the open ocean.

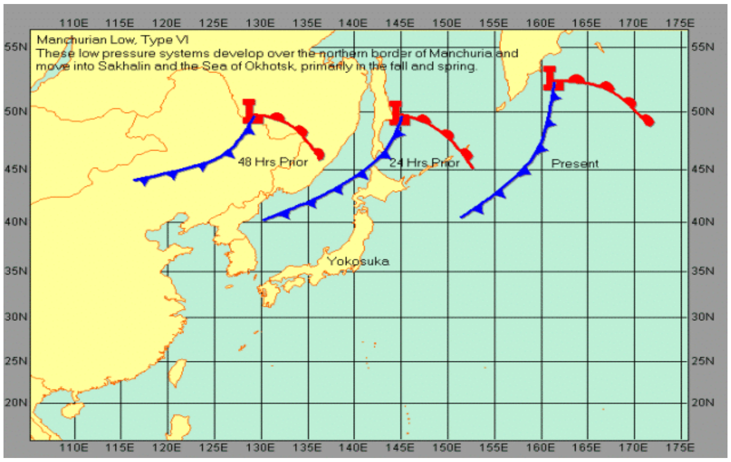

FIGURE 4-3. MANCHURIAN LOW

(2) Lake Baikal Low. The Lake Baikal Low, see figure 4-4, develops in the vicinity of Lake Baikal in central Siberia as winter storms progress along the Siberian Storm track. This system may develop during any season but is most common during spring. The average speed of this system is 22 knots. The track of the Lake Baikal Low (similar to the Manchurian Low) passes through the Soya (La Perouse) Straits before entering the north western Pacific. Again, very little weather is associated with the Lake Baikal Low until it reaches the open waters of the Pacific.

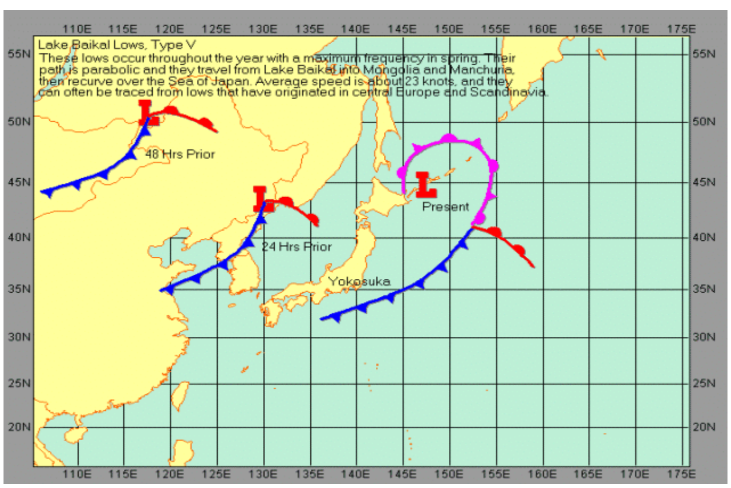

FIGURE 4-4. LAKE BAIKAL LOW

(3) South Mongolia Low. The South Mongolian Low, figure 4-5, is caused by leeside troughing over the Altair Mountains when a storm impulse aloft approaches from the west along the Icelandic Storm Track. It generally tracks from its source

region southeastward to northern North Korea before exiting into the Sea of Japan. The South Mongolian Low will normally turn to the northeast, tracking over Hokkaido before reaching the southern Sea of Okhotsk and the western Pacific. It can develop during any season, with an average speed of 20 knots.

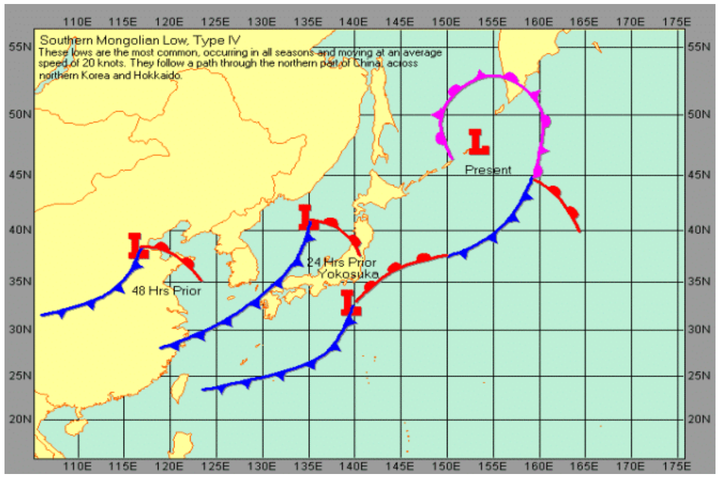

FIGURE 4-5. SOUTH MONGOLIAN LOW

b. The Southern Lows. The Southern Lows generally form over central and southern China, then track eastward to either the Sea of Japan or south of Japan between Kyushu and Okinawa. These systems may occur year round and produce widespread precipitation, low ceilings, poor visibility and occasional squall lines. The source region for the two major systems in this group is the Shanghai area. The generation area of the supporting upper-level, short-wave troughs which form these lows and their subsequent tracks further delineates these systems.

(1) Yellow Sea Low. The Yellow Sea Low, figure 4-6, occurs primarily during the summer and autumn, tracking at an average speed of 20 knots. It develops in the area between Shanghai and Osan and tracks to the northeast over Korea, through the Sea of Japan and across northern Japan to the western Pacific. This system may also produce a double-eyed system south of Kyushu or Shikoku within 12 to 18 hours after entering the Yellow Sea. Without development of the “double-eye” system, strong southwest winds will develop on the leeside of Japan.

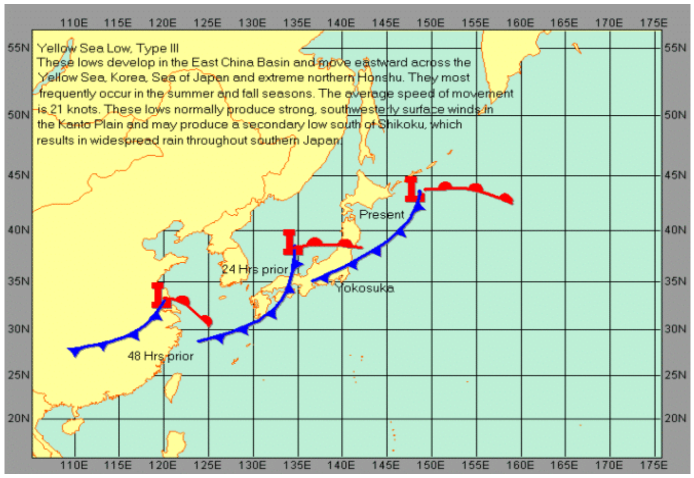

FIGURE 4-6. YELLOW SEA LOW (DOUBLE EYE)

(2) Shanghai Low. The Shanghai Low, see figure 4-7, occurs most frequently during the spring. The Shanghai Low is subject to rapid intensification as it moves over the warm waters of the Kuroshio Current (much like the “Hatteras Low” along the east coast of the U.S.). It moves from the source region in central China, often developing along a stagnating frontal system, then tracks to the east or northeast to the southern coast of Japan. The average speed of the system is 20 knots as it passes south of Kyushu. The main low center sometimes tracks into the Sea of Japan with a secondary low forming on the leeside of Japan near Shikoku. The two low pressure centers of this double-eyed system will track northward together until they merge over northern Honshu/southern Hokkaido and move into the western Pacific. During late spring through early autumn, a cyclone family will form along the polar front generated by low formation. If the system takes a more northerly track, north of 32° N, precipitation will dominate the Japanese islands.

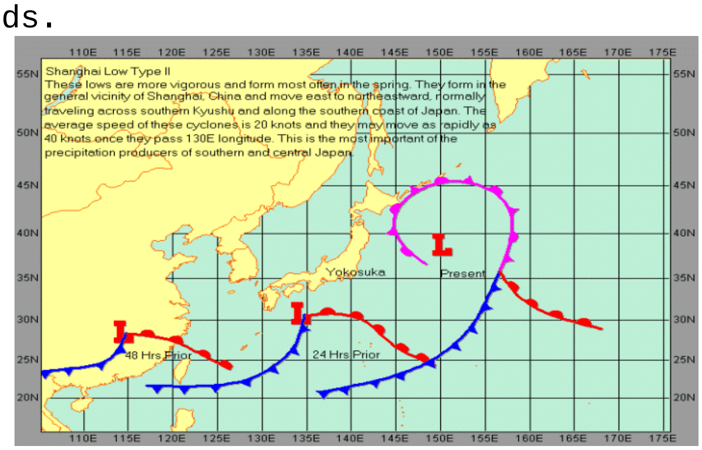

FIGURE 4-7. SHANGHAI LOW

(3) Taiwan Low. The Taiwan Low, see figure 4-8, generates over China near 25° North and 100° East, occurring most frequently from autumn through spring. This system will often form as a wave on an active stationary front and track northeastward at an average speed of 25 knots. The Taiwan Low will always pass south of Japan; however, depending on the long-wave pattern, the system may pass close enough to Japan to produce precipitation over the islands. Wave formation along the front associated with a Taiwan Low is common and forms under several circumstances.

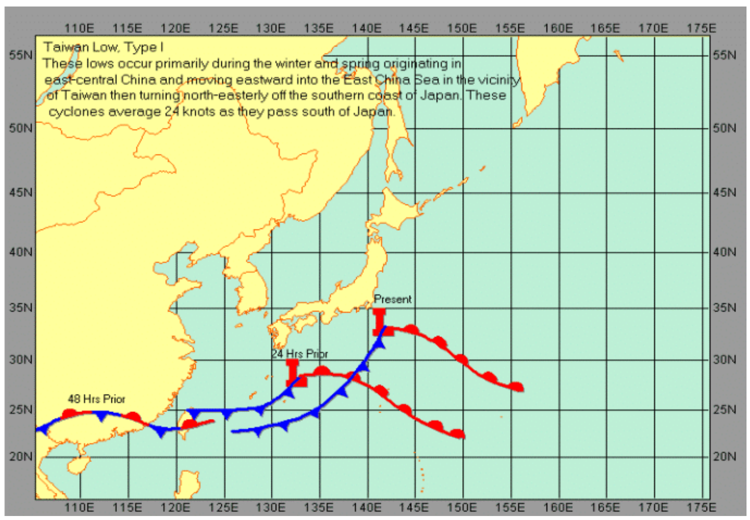

FIGURE 4-8. TAIWAN LOW

c. Stationary Systems

(1) Sea Of Okhotsk Low. A stationary system will develop in the Sea of Okhotsk extending from the surface through the 500 mb level. This system serves as the anchor low, indicating that the long-wave trough is in the vicinity of 150° East. Lows tracking along the northern storm tracks will be steered toward the anchor low. Northern systems will be relatively dry, as migratory lows will not reach the western Pacific. Further development of the Shanghai and Taiwan Lows will be supported when strong impulses move along the central and southern storm tracks. Combination of the anchor low with the dynamic system causes a retrograde action of the long-wave to a northeast-southwest orientation.

(2) Mei-Yu (China/Taiwan)/Bai-U (Japan)/Chang-Ma(Korea) Fronts. The Mei-Yu/Bai-U/Chang-Ma front, see figure 4-9, is a quasi-stationary system occurring during the transition period

between the Northeast Monsoon in the winter and Southwest Monsoon in the summer. The front initially develops as the western extension of the subtropical high extends over southern China and Taiwan. Dissipation occurs when the seasonal monsoon becomes fully established. The Mei-Yu/Bai-U front is a relatively shallow feature, developing only in the lower troposphere, thus characterized by only a narrow band of precipitation with areas of embedded showers and isolated thunderstorms. A significant low-level jet (LLJ) is also associated with the Mei-Yu/Bai-U front. Jet maxima are located near the 700 mb level and usually 180 NM southeast of the most active areas of convection. Weak mesoscale circulations, with embedded clusters of convective cells, compose the frontal structure of the Mei-Yu/Bai-U front. Along the active front in the vicinity of Taiwan, frontal lows develop every 17 to 20 hours, moving eastward at 10-15 knots. South of Japan, lows form every 20 hours; however, the speed of movement increases to 25-30 knots. Deepening of these lows will occur if the front interacts with a mid-latitude upper level trough east of 135° East.

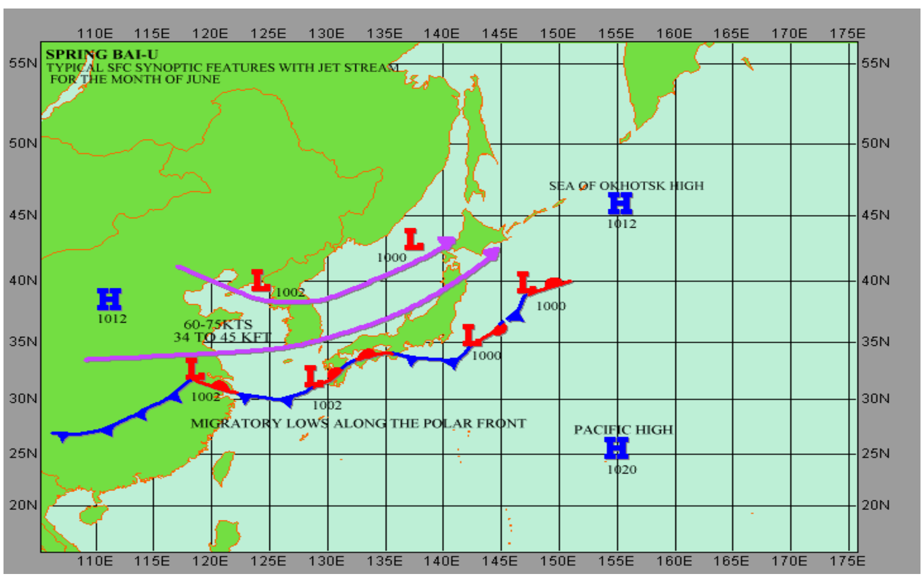

FIGURE 4-9. BAI-U FRONT

d. Cyclogenesis. The east coast of Asia and the south coast of Japan provide a naturally favorable climate for recurring cyclogenesis. Continental Polar air masses are either in close proximity to warm maritime air masses or are undergoing rapid modification as they move over the warmer waters of the East China Sea, Yellow Sea, or the Sea of Japan. Several synoptic patterns that aid in cyclogenesis or frontogenesis are described in the following sections.

(1) Bubble High Cyclogenesis. The most reliable indicator for cyclogenesis in the cool season is the off-shore movement of a cold, migratory high pressure cell from the Siberian High commonly known as a “Bubble High”. Cyclogenesis will normally occur 24 to 48 hours after the high moves off the coast. Its location will roughly correlate with the latitude of the Bubble High, see figure 4-10. Highs that track north of 35° North will generate lows that move into the Sea of Japan. Highs that track south of 30° North will generate lows that move south of Honshu. Cyclogenesis will normally occur in the Yellow or East China Seas (Yellow Sea or Shanghai Lows respectively). Highs moving off-shore between 30-35° North produce lows whose movement depends upon their position within the jet stream. Lows that develop north of the jet will initially move southeast toward the southern boundary of the jet, deepening rapidly as they pass under the jet core. Bubble High Cyclogenesis has been such a consistent weather phenomenon that it can be reliably forecasted with little error. The lag period between the high moving offshore and the formation of the low is 24-36 hrs in the winter and 36-48 hrs in the spring and summer. If a pre-existing low exists to the northwest of the area of cyclogenesis when the high initially moves offshore, two cyclones or one elongated north-south cyclone south of the bubble high will usually form. This system will become better organized as it reaches the East China Sea, having moved off the central China coast, producing a Shanghai Low. This pattern is typical during the winter and has a lag period of 24 hrs. When a pre-existing cold front is present to the northwest of the bubble high, cyclogenesis will usually occur along the front in the vicinity of the northern Yellow Sea. The low, with an inactive warm front, will move northeastward through the Sea of Japan. This Yellow Sea Low usually occurs in early or late winter and has a time lag of 24-36 hrs. If cyclogenesis does not occur, weather will be restricted to a narrow band along the front. When no existing low or front is present at the time of cyclogenesis, a wave cyclone will form in the central and southern coastal regions of China and move along the southern coast of Japan, producing a Taiwan Low. These lows usually occur in spring and autumn, with a lag period of 36 hrs and will usually take 3 to 4 days to pass east of the Japanese coast. Once these lows form, they deepen rapidly, averaging a 10-15 mb pressure drop in 24 to 36 hrs. This rapid deepening of the Taiwan Low is primarily due to the thermal contrast between land and water, as well as favorable upper air conditions.

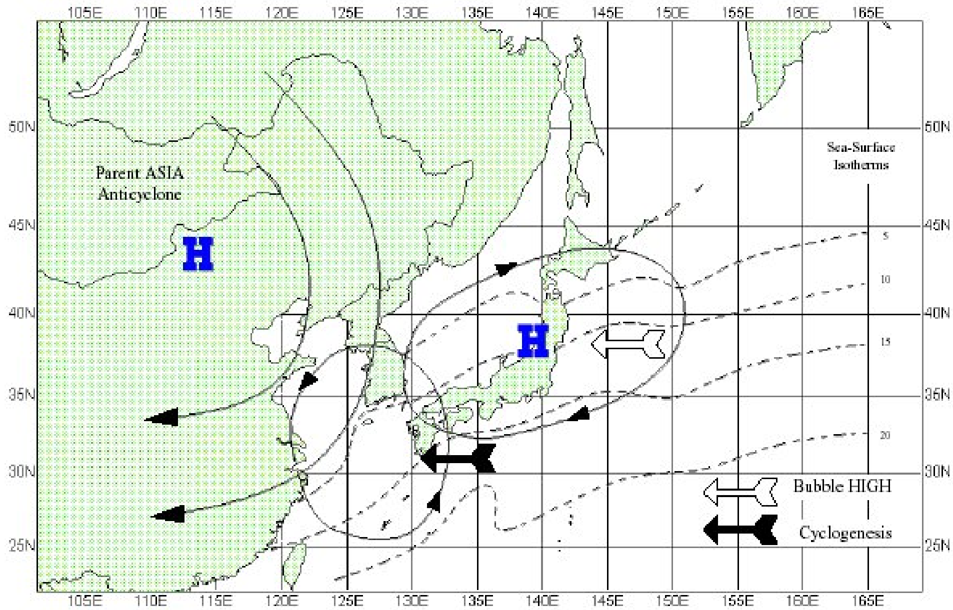

FIGURE 4-10. BUBBLE HIGH CYCLOGENESIS IN EAST ASIA

(2) Cool Season Cyclogenesis. Cyclogenesis will occur along the southern coast of Japan when surface troughing is evident over the Kuroshio current south of Japan, the pressure gradient is weak, upper level short wave troughs moving through the area are slow and the air-sea temperature difference is greater than 13° F (7° C). Lows developing in this area are called “Oshima Lows” since they develop in the vicinity of Oshima Island. The development of this low is seen as a wave on the 850 mb level with a developing system in the Sea of Japan near 125-130° East. Another indication of low formation is the presence of a low-level jet (LLJ) from the south in the vicinity of Hachijo Jima (RJTH). During cool season cyclogenesis, there is a marked onshore flow over southern China with cold continental air in close proximity to cool maritime air. Development of a Taiwan Low is possible during this period. An 850 mb short wave trough bringing a surge of cold air to the area will be a major factor influencing cyclogenesis.

(3) Warm Season Cyclogenesis. A short wave trough moving into a well-defined cool/cold tongue indicates a possible area of cyclogenesis. Cyclogenesis will usually occur when the short wave trough approaches to within 41-50° F (5-10° C) of the cool tongue of air. Warm Season Cyclogenesis is most prevalent in the Yellow Sea and Sea of Japan.

(4) Stationary Front Cyclogenesis. Cyclogenesis along a

stationary front south of Japan generally occurs when the following two conditions are met: upper level winds must be from the west to southwest and the front is stalled within 300 NM of the southern Japanese coast. The formation of a lee-side depression between Oshima Island (RJTO) and Hamamatsu (RJNH) will occur when the low-level winds along the southern coast are from the west-southwest and from the north-northeast along the southeastern coast of Honshu. Cyclogenesis will be indicated by thermal packing on the 850 mb chart. Cyclogenesis along the stationary front will also occur when an upper level cold low is located in the Manchuria-Siberia region with cyclonic flow occurring near the polar front.

(5) Transition Season Cyclogenesis. An area of possible cyclogenesis will establish itself off southern Kyushu in the deep cool easterly flow, becoming active when the gradient winds along the southern coast of Japan veer northeasterly and the 850 mb winds are light and southerly. This pattern typically occurs in the spring when the ridgeline is established over the Kanto Plain. During late summer and early autumn, the subtropical ridge will establish a deep easterly flow over Japan and low-level cool air is present in the generating area, such as when a cool high-pressure system tracks southeastward off southern Japan and advect cold air into the region. The trigger is usually a short-wave trough moving over the Korean peninsula.

(6) Lee-Side Depressions. Weakening of the local pressure gradient over the Sea of Japan accompanied with moderate to strong west to southwest low level wind flow parallel to the mountains of southeast Japan will generate lee-side depressions/troughs along the southeast coast of Japan. These systems should be closely monitored for explosive deepening and rapid movement. Lee systems may develop when the following conditions exist:

(a) Northerly flow along the mountains of south central Honshu.

(b) A short wave approaching the area.

(c) A low moving through the Sea of Japan.

(d) Cold fronts approaching Japan, parallel to the coastal mountains.

(e) Pressure falls and troughing occurring south of Kyushu and/or Shikoku.

e. Lake Baikal Migratory Highs. Many regions of Asia are favorable high-pressure producers due to extensive hours of darkness over vast cold landmasses during the winter seasons. As with the low-pressure systems discussed above, these high-pressure systems follow a definite pattern or track according to the season. There are three significant stagnating, semi-permanent, high-pressure cells from which dynamic highs affecting the western Pacific originate. These cells are predominantly cold weather features that disappear during the summer months. They are important to the forecaster since they give a “first-glance” clue to the presence or absence of blocks to winter storm tracks.

(1) West. The West Lake Baikal High is a semi-permanent feature that will disappear for short periods under the influence of impulses traveling along the Icelandic track. When the West Lake Baikal High is firmly established, a storm must track either along the Siberian storm track or along the southern track. The West Lake Baikal High has the highest central pressure of any system in the Northern Hemisphere, averaging 1,055 mb and reaching 1,088 mb during very cold winters.

(2) East. The East Lake Baikal High is mainly a summer and early autumn feature. This High will generally move to the southeast over northern Korea, through the Sea of Japan and over northern Honshu and Hokkaido.

(3) Northeast. The Northeast Lake Baikal High is a semi-permanent feature that disappears for short periods of time under influence of a strong impulse traveling along the Siberian or Icelandic Storm Tracks. When the High is firmly established, a blocking situation sets up along the northern tracks. At various times during a winter season, the Northeast Lake Baikal and the West Lake Baikal High will combine into one smoothed system, the Siberian High.

4. Monsoon Cycle. The term "monsoon" originated from the Arabic word "mausin", which means season. It originally applied to the wind regimes of the Arabian Sea where winds blow for six months from the northeast (Winter Monsoon) and six months from the southwest (Summer Monsoon). The predominant characteristics of the monsoon regions are: 1. Prevailing winds shift by at least 120 degrees between January and July; 2. Average frequency in prevailing directions in January and July exceeds 40%; 3. The mean resultant winds in at least one of the

months exceeds 3 m/s, and less than one cyclone/anticyclone alteration occurs on average every two years in any one of the months in a 5 degree latitude-longitude rectangle. There are three main factors that account for the existence of the monsoons: 1. Differential seasonal heating of the oceans and continents. Seasonal contrasts in land surface temperatures which produce atmospheric pressure changes that cause seasonal reversal of the pressure gradient force, which is the basic driving force of the winds; 2. Moisture processes in the atmosphere consist of moist warm air rising over summertime heated land surfaces. As the moisture eventually condenses, latent heat of condensation is released in the atmosphere. This extra heat raises summer land-ocean pressure differences to a point higher than they would be in the absence of moisture in the atmosphere; 3. The Earth’s rotation causes the coriolis parameter which forces air from high-pressure areas to spiral into low-pressure areas with a change in direction as winds cross the equator.

a. Annual Monsoon Cycle. The relationship between the general mechanisms that generate the monsoons, the seasonal climate cycle and the annual monsoon cycle, are as follows. In the transitional months between the southern and northern hemisphere summers, ITCZ is located in the equatorial regions where maximum surface heating can be found. During this period of time, the northern hemisphere tropical-subtropical latitudes are beginning to warm. Vertical motion is present, but weak. The northern Hadley Cell still predominates at this stage. With the northward movement of the sun in May to June, the heating of northern tropical landmasses intensifies, as does the vertical motion over these landmasses. Northern tropical atmospheric moisture contents also increase as the southern hemisphere’s Hadley cell intensifies; the predominant wind direction is onshore. By May to June, belts of precipitation associated with the ITCZ have moved well north of the equator, signaling the onset of the summer wet monsoon. When this occurs, the ITCZ looses its identity and undergoes a transformation into a Monsoon Trough as it merges with the heat lows that form along the warm coastal areas from Kenya, the Arabian Peninsula, Pakistan, India, and Bangladesh. By June to July, after the summer solstice, sensible heat input from the sun at the surface is close to its maximum, as is the vertical motion and atmospheric moisture over the northern hemisphere tropical landmasses. Maximum values of the pressure gradient force between the Mascarene High and Monsoon Trough have also been attained by this stage and the monsoon reaches its maximum intensity. The rush of northward air over the equator is subject to the Coriolis Force and can generate a jet-like wind such as the Somali Jet (Cross-equatorial flow and upwelling along the Somali Coast). The outflow of air in the upper atmosphere, above the surface thermal lows, are also affected by the Coriolis Force and produce strong easterly jet-like winds on the southern side of anti-cyclones. At this stage the amount of precipitation and the monsoons northern most extent has reached its maximum. September, with the Autumnal equinox, surface heating has decreased markedly with maximum insolation now positioned close to its April position. The ITCZ re-emerges and is located near the equatorial regions north and south of the equator. September also brings to an end the southwest monsoon and onset of the dry season. By December the southern hemisphere wet season is well under way as the precipitation belts associated with the ITCZ and development of a monsoon trough have moved well south of the equator. In the North Arabian Sea and the Bay of Bengal, the northern hemisphere Hadley cell has become the dominant feature. The most important factor contributing to the monsoon is topography: The Himalayan and Hindu Kush mountain ranges in India average over 14,000 feet (600 mb) and extensive areas exceed 18,000 feet (500 mb) and are an effective barrier to any surface interaction between the Indian Ocean and the Eurasian mainland north of the mountains. Throughout the year, it is impossible for cool air to intrude southward past the barrier. The Tibetan Plateau also has a significant effect upon both the Northeast and the Southwest Monsoons. With the change from a semi-permanent high to a semi-permanent low over the plateau, the resultant cyclonic circulation enhances and aids the general circulation south of the Himalayas. The timing of the changes of weather patterns in the Tibetan Plateau is crucial in determining an early, normal, or late onset for the monsoon.

b. Variability of the Monsoons. In reality, there is considerable variability in onset, duration, and magnitude of monsoons. The mechanisms responsible for monsoon inter-annual variability may be categorized into two groups: internal dynamics and boundary forcing. Internal dynamics can be influenced by tropical disturbances, thermal and orographic forcing, non-linear associations between different scales of atmospheric motion and tropical-extra tropical interactions, all acting together to produce a periodic variation in onset, duration and magnitude. Boundary forcing refers to changes in surface conditions. Arial extent of snow cover with the Tibetan Plateau, widespread ocean and land surface hydrological effects, and the sea surface energy balances tropospheric thermodynamics. Changes in boundary conditions affect the geographic distributions of heat and moisture sources and sinks, thus the pattern of moisture bearing tropospheric winds. Monsoons also experience intra-seasonal variations in the form of active and break phases equating to rainfall increase, decrease or the absents of rainfall, and surges in the boundary layer wind flow. Transition of seasons in general and onset in the South China Sea has shown variation of up to two to four weeks (Gedult von Jungenfeld, 2000). The most reliable transition occurs in the fall due to the rapid cooling of the hot-cold regions of central and southern China and Russian Siberia. The coming of a cold surge signals the end of the southwest monsoon. The spring transition occurs in three stages starting in the North Arabian Sea, then into the Bay of Bengal, and finally settling in the South China Sea and Southern China. Prior to onset, winds have a remarkable variability between southwest and northeast in the South China Sea before the Monsoon vortex becomes firmly entrenched in Central Asia.

c. Northeast Winter Monsoon. The Northeast Winter Monsoon is a result of a reversal of wind flow over tropical and subtropical regions from a southerly wind component to a northerly wind component. These "northeasterly" winds signal the start of the Northeast or Winter Monsoon. Several phenomena, such as cold surges, described as part of the northeast monsoon can be thought of as mid-latitude weather phenomena as they are associated with cP outbreaks. They are discussed here because they fit into the monsoon cycle. The origin of the Northeast Monsoon is in the rapid cooling of the interior of Asia, the establishment of the Siberian High and of high-pressure cells that dominate western Russia and China during the subartic winter. As high pressure cells form and migrate southeastward as intense cold surges, strong north to northeasterly wind flow is set up over eastern Asia and adjacent waters that extend well into Southeast Asia. The pressure gradient winds are particularly strong in the Yellow Sea, the Sea of Japan, the Pacific Ocean south of Japan to Iwo Jima and Okinawa, the Taiwan Strait, and the South China Sea. The strong northerly wind flow is capable of producing large gale areas and high seas for extended periods of time. The winter monsoon season dissipates as the cold highs weaken during the spring, resulting in the migration of the Polar Front north to its summer position, see figure 4-11.

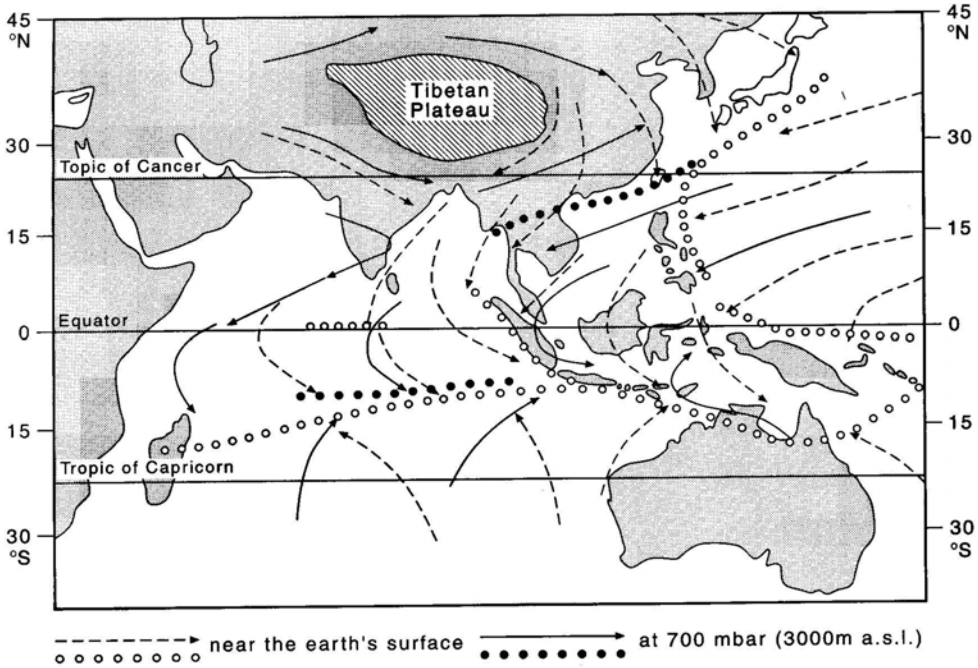

FIGURE 4-11. THE ASIAN WINTER MONSOON
(TROPICAL CLIMATOLOGY, MCGREGOR AND NIEUWOLT, 1998)

d. East Asian Winter Monsoon. With the onset of the northern winter the predominantly cyclonic circulation pattern over eastern Asia is replaced by an anticyclonic pattern. The associated high-pressure center reaches a great intensity at about 40°- 60° North over Mongolia and middle Siberia. Regions within this high experience very low ambient temperature due to long wave radiation loss under minimal cloud cover and minimal shortwave gains due to high albedo of snow cover. Air moves out from the anticyclonic center in a southerly direction over Korea, China, Japan, and Indo-China and the western Pacific. At about 15°-20° North, over the South China Sea, the northerly airflow converges with the northeasterly winds from the Pacific. The two air currents merge gradually on their way to the southwest where they form the northeast monsoon of Southeast Asia. Onset of the Northeast Monsoon in September is related to three major features of the circulation. The first is the monsoon trough. By September the large scale Monsoon Trough has moved south from the northern South China Sea and has set up in a quasi-stationary position over the equatorial South China Sea (Maritime Continent) and is referred to as the Northern Near-Equatorial Trough. Northeasterly trades prevail to the north of this trough. The second feature is a surge of cold air within the northerly monsoon current from the northern Asian anticyclone system over Southeast Asia. The third feature is the reversal of upper level winds from easterly to westerly over southern China and northern South China Sea. Compared to the summer monsoon, winter monsoons are shallow. Near its origin the cold anticyclonic high does not reach to great heights confirming its thermal origin. Over most of the Asian continent, winds at 700 mb are westerly which means that the northerly winter monsoon is below 700 mb. Westerly winds flow mainly on the southern side of the Tibetan-Himalayan Plateau but a westerly flow is also maintained on the northern side of the plateau. The confluence zone may reach as far as southerly Japan. Within this zone cyclogenesis may develop. Further south, where the winter monsoon is reinforced with the north Pacific trades, the monsoon may reach to levels above 700 mb.

(1) Northern Hemisphere Cold Surges. A distinct characteristic of the winter monsoon in East Asia is periods of very cold weather related to cold surges with the winter monsoon. Cold surges will affect the tropical regions because of the northeast monsoon flow. In the initiation stage, baroclinic processes related to large north-south temperature gradients and the pooling of cold air to the north of the Tibetan Plateau appear to be important primers for surge onset. The Tibetan Plateau acts to block movement of polar continental air to the south, trapping it, and enhancing the Siberian high through positive feedback mechanisms. The thermal gradient becomes greatly enhanced and accentuates the intensity of the baroclinic zone between cold northerly air and warm southerly tropical air. There are on the average 13 cold surges in each winter season (October to April), of which two are strong cases. The average intensity of cold surges is 1,053 mb and originates northwest of Lake Baikal or north of Lake Balkhash. The typical evolution of a cold surge occurs over the period of 5-14 days. To the east of the Tibetan Plateau, over the western Pacific, between Japan and the Philippines at about 130^{o} East, a quasi-stationary upper level westerly trough (with a length of about 500 km) is maintained during the winter. Through this trough, shortwave disturbances in the form of cyclonic vorticities travel. The effect of these is to spark off intense periods of anticyclogenesis over northern China and cyclogenesis over the eastern parts of the South China Sea. Associated with these changes is a downstream acceleration of the upper westerly jet over East Asia. This produces a steep meridional pressure gradient over East Asia with the result that there is a burst of cold air from northern China along the east coast of China and over the South China Sea. The equatorial propagation phase has two stages. The first stage is characterized by a rise in pressure over the South China Sea. Propagation speeds in this

stage have been measured between 52-77 knots (24m/s-10m/s). The second stage is associated with a sharp decrease in humidity as cold dry air streams out from northern China. Wind speeds may increase in either of the stages. A southward moving cold front is only seen in the second stage moving at an average speed of 21 knots and can reach all the way south of the equator. The maximum frequency of cold surge occurrence occurs over the South China Sea between 10° and 20° North and 110° to 118° East. A less high frequency occurs east of the Philippines. Cold surges occur most often in December with secondary peaks in the months of November and January. Events are characterized by below normal temperatures and above normal wind speeds and may last between 4 to 6 days. Most forecast models pay close attention to atmospheric dynamics in the cold surge source areas over the Arctic seas and Russian and Siberian lowlands, especially the Lake Baikal area at 90° East. The inter-annual variation of averaged meridonial wind near the South China Sea and the Maritime Continent is dominated by South China Sea cold surges and is also well correlated with the Southern Oscillation Index (SOI), related to El Nino/La Nina oscillations. Strong wind seasons are associated with La Nina and high SOI events; weak wind years are linked with El Nino and low SOI events. This pattern is restricted north of the equator within 0°-20° North, 110°-130° East and is confined to the near surface. The Siberian High, 500 mb shortwave, 200 mb jet stream, all representing the large-scale monsoon flow, are found to be weaker than normal during El Nino years.

e. Transition to the Trade Wind Season. During March and April in the western Pacific, and as the eastern Asia interior regions start to warm, the western Pacific Subtropical High establishes south of Japan and centers around the island of Bonin as the Bonin High. East Asia is still cold enough to produce outbreaks that bring frontal systems to the southeast over the East China Sea and the Philippine Sea. These cold fronts are greatly modified as they move over the warmer water of the Kuroshio Current and take on the characteristics of the surface over which they flow, thus losing their thermal identity. Winds behind these fronts remain strong and shear lines are formed, remnants of frontal systems that can only be recognized by wind discontinuity behind and ahead of the front, as thermal discontinuity has been so modified that a frontal zone can not be recognized. The Western Pacific Subtropical High develops with help from outflow of a strong Hadley cell and with the monsoon trough well established in the Maritime Continent. Centered on the month of April, the resulting winds in the East China Sea, Philippine Sea, and South China Sea take on an east-northeast trade wind component that extends well into Southeast Asia and into much of the Bay of Bengal at the southern periphery of the subtropical ridge. The transition and establishment of the trade wind season sets up the stage for the reversal of wind flow by May to once again to start a southwest monsoon season.

f. Southwest Summer Monsoon. The Southwest summer monsoon in Southeast Asia is synonymous with the East Asian monsoon used in some textbooks and generally describes the monsoon of Indochina, Philippines, southern and eastern China, and Japan and Korea. In general, the Southwest Monsoon (mid-May to September) has heavy and frequent precipitation, high humidity, and, except at higher elevations, high temperatures. This is in contrast to the Northeast Monsoon, which usually brings little precipitation, lower humidity and cooler temperatures. The monsoon is controlled primarily by the large semi-permanent pressure systems of Asia and adjacent oceans, see figure 4-12; warm, moist air from the tropical oceans flows towards the Asian continent.

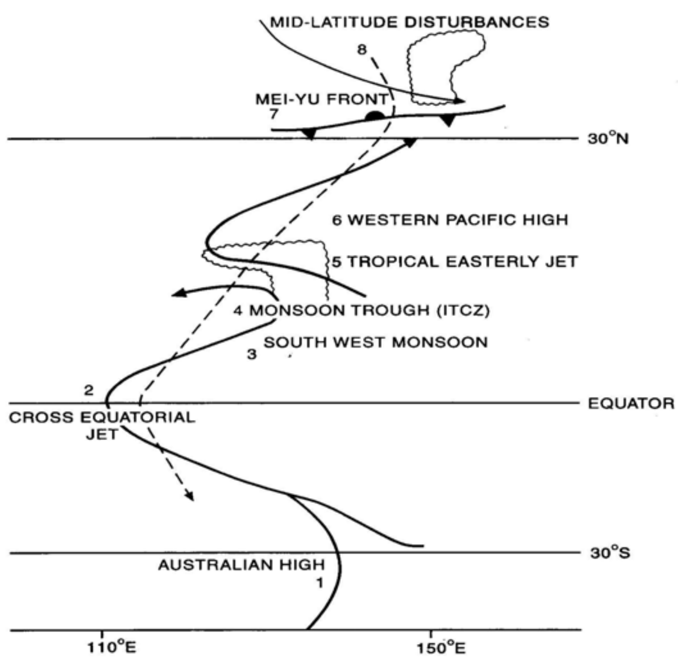

FIGURE 4-12 THE ASIAN SUMMER MONSOON
(TROPICAL CLIMATOLOGY, MCGREGOR AND NIEUWOLT, 1998)

(1) Structure of the Southwest Monsoon. The Southwest (East Asian) Monsoon in Southeast and East Asia can be divided into seven major components as depicted in, refer to figure 4-12:

(a) The Australian High

(b) The cross-equatorial jet at about 110^{o} East

(c) The Monsoon Trough

(d) Zones of convergence (SPCZ and ET)

(e) A Tropical Easterly Jet

(f) The western Pacific High

(g) The Mei-Yu Front

(h) Mid-latitude disturbances

In addition to the cross-equatorial flow from the southern hemisphere, the East Asian Monsoon also originates in airflow from two other air mass regions. They are from the Indian Ocean, source of the Indian summer monsoon airflow, and the western Pacific from where the southeast monsoon flow emanates from the western flanks of the western Pacific High. The cross-equatorial flow from the southern hemisphere is an extremely important component of the East Asian monsoon, as it carries large amounts of moisture in inter-hemispheric mass exchange. The airflow is initially stable and dry over the Australian continent until it reaches Indonesia and crosses the Maritime Continent. There, as it comes under the influence of Coriolis force and crosses the equator in the deep tropical regions, the air becomes very moist and extremely unstable. This moist unstable air is an important energy source for tropical cyclones in the western Pacific. The eastern limit of the southwest monsoon extends to and over the Philippines where it competes with influence of the western Pacific Subtropical Ridge for position. It can be said that, except for the month of August, it is mostly the effect of tropical cyclones approaching from the east that draws the monsoon over the central and northern portions of the Philippines. An exceptionally important structural feature of the summer monsoon is the monsoon trough, which stretches from the western Pacific across the Philippines into Indochina. The trough region is very high in humidity, has some form of cyclonic convergence, cluster cloudiness, and rainfall and is characterized by wet, cloudy, and often windy weather.

g. Summer Monsoon in Korea and Japan. The Southwest

Monsoon in the Korean and Japan region has its origins from the backside of the western Pacific Subtropical Ridge, refer to figure 4-13. The subtropical high (Bonin High) is especially important during the July to end of August timeframe. During this period the western Pacific High moves rapidly northward, as does the ITCZ to the southwest. At its origin, the air in the Subtropical High region is dry and stable and the atmospheric structure is dominated by a trade inversion.

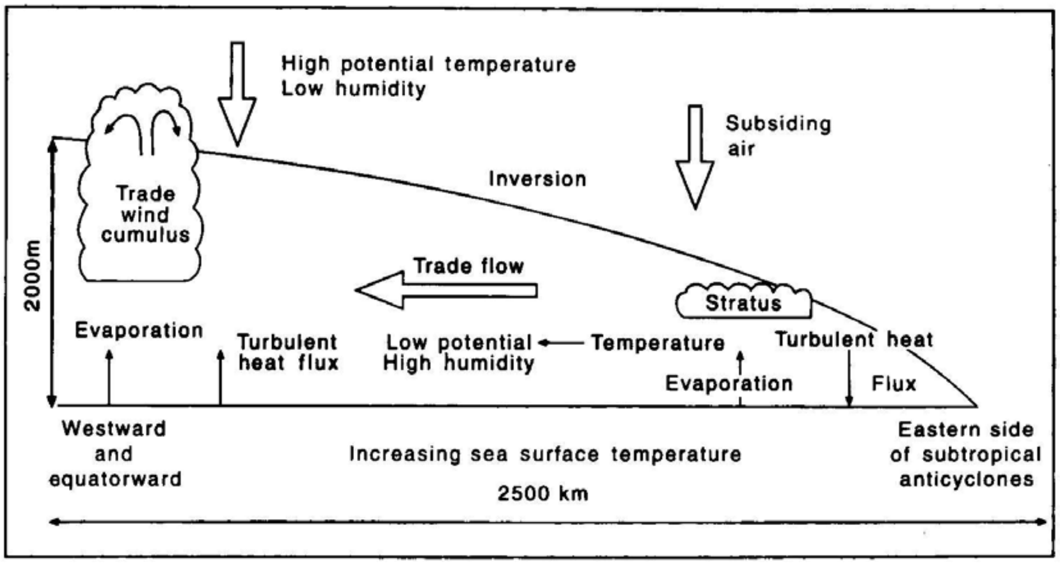

FIGURE 4-13 THE TRADE INVERSION. FROM WELLS, 1986 (TROPICAL CLIMATOLOGY, MCGREGOR AND NIEUWOLT, 1998)

As the Subtropical High air moves westward and surface heating results in increased sea surface temperatures, it is rapidly modified and becomes unstable as it turns northwestward. Consequently, moist warm air is advected west to the Philippines and merges with the southwest flow. This creates a north-south convergent zone over the Philippines that extends northeast to Okinawa and Japan. East and south of this convergent zone the air is maritime tropical, while north of this convergent zone it is modified continental polar air. This zone of convergence occurs during May and June and is part of the Bai-u Front that occurs late spring to early summer over Japan with widespread cloudiness, periods of rain, and imbedded convective activity. Thunderstorm activity is rare but can be observed off shore during interaction the Kuroshio Current. As summer progresses, this zone of convergence migrates north with the polar jet and shifts the Bai-u front north to lay east-west over Korea and northern Japan, pushing the monsoon north over that area. Japan comes under the influence of the subtropical ridge with hot and very humid conditions. The zone of confluence with the cross-equatorial flow from the Australian region is generally to the east of the Philippines reaching southern Japan and Korea during the height of the summer months. Generally, the southeasterly component of the East Asian monsoon is greatest over the South China Sea, southern China, and Japan.

CHAPTER 5
Tropical Cyclones

1. Tropical Meteorology Fundamentals. The tropics encompass the region between 23° North and 23° South of the Equator, exhibiting barotropic disturbances and little temperature advection. Additionally, pressure differences in the tropics are so weak, most weather disturbances cause pressure fluoxuations indistinguishable from noise. Consequently, important persistent features are better defined by resultant winds and streamline analyses than by pressure and pressure-height fields which tend to have small gradients. In a streamline analysis, the wind fields are kinematically analyzed and lines depict the wind flow. The most analyzed levels in the tropics are the surface/gradient level and 200 mb, primarily because observations are available at those levels. The gradient level is defined as the lowest level with friction free flow (3,000 ft or 1 km). Where drawn through large mountain barriers, gradient-level flow has little or no meaning. Along the equator, where Coriolis force approximates zero (because the earth is not perfectly round, the coriolis force never goes to zero), a zero balance is struck between the mean pressure gradient and mean friction. The mean resultant wind then blows perpendicular to isobars, from high to low pressure. During El Nino, the pressure gradient over the equatorial Pacific often reverses to west-east and westerlies replace easterlies. In much of the tropics, the two main seasons (wet and dry) are separated by relatively brief transition seasons. Thus, mid-season months (January, April, July, and October) describe the annual cycle very well.

a. Monsoon Trough Development. The monsoon and near-equatorial troughs are elongated regions of low pressure at the gradient wind level related to the location of the seasonal trade wind troughs, monsoon troughs, and equatorial buffer zones, see figure 5-1. In spring and early summer, solar heating near the equator produces the near equatorial troughs as trade wind troughs. When a westerly wind component is added to the trade wind trough, the result is a monsoon trough. Forecasters monitor the monsoon trough closely because it is in these troughs where tropical cyclone activity develops and in cyclonic turning for cyclonic lows to develop. When analyzing the monsoon trough, look for westerly winds on the equator-side of the trough. This is true for both the northern or southern hemispheres. It is very rare for the Pacific Ocean to have tropical waves develop into tropical cyclones without a significant westerly wind component. The summer and early autumn monsoon trough is recognized as being the greatest producer of tropical cyclones in the western Pacific.

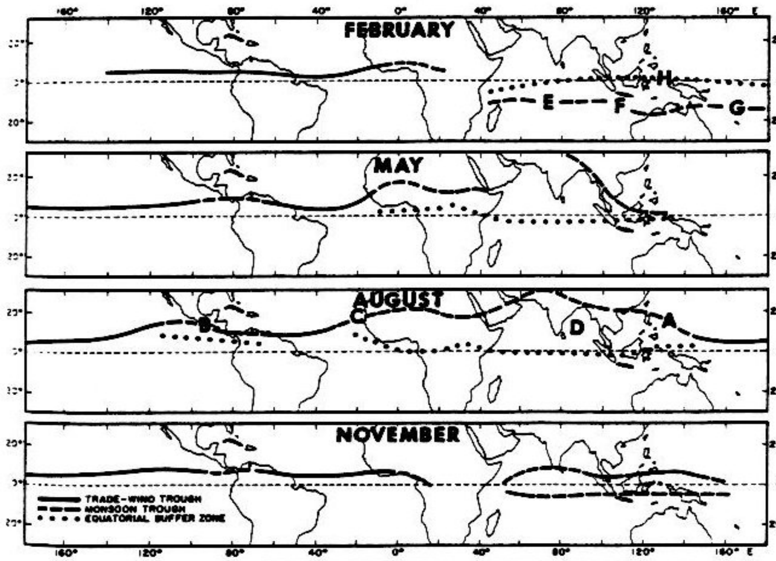

FIGURE 5-1. SEASONAL POSITIONS OF THE MONSOON TROUGHS (ADAPTED FROM ATKINSON AND SADLER, 1970)

b. Tropical Upper-Tropospheric Trough (TUTT). A surface disturbance can be induced by upper-level divergence associated with the eastern side of a cyclonic cell in the TUTT (Sadler, 1976). This type of development occurs most frequently during the August to October timeframe due to the strength of the TUTT and accounts for 10% to 20% of the tropical cyclones that develop. These disturbances, which usually occur between 15° to 25° North, undergo three stages of development as shown in figure 5-2.

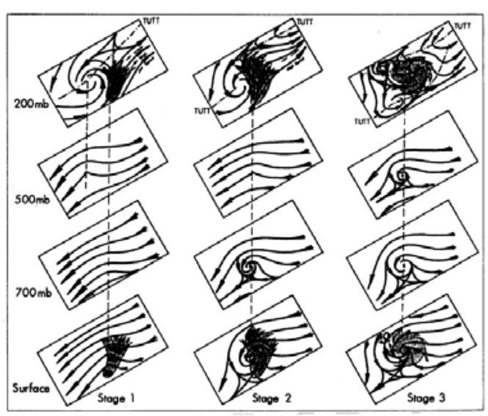

FIGURE 5-2. THREE STAGES OF THE TUTT (ADAPTED FROM ATKINSON AND SADLER, 1970)

c. Tropical Cyclones and Genesis Areas. The term “tropical cyclone” applies to a non-frontal low pressure system of synoptic-scale, developing over tropical or subtropical waters having definite organized circulation. However, the term is generally used in a more restrictive sense to include only potentially destructive warm-core systems; thus, the operational definition excludes monsoon depressions and mid-troposphere and subtropical cyclones. Tropical cyclones are barotropic and possess a cyclonic surface wind circulation and are characterized by circular isobars around the center of low pressure. Tropical cyclones are the most destructive weather phenomena for their size. These weather systems function as natural, but very inefficient, “heat engines”; with most of the latent heat energy that is released expelled high in the atmosphere. Only a small percentage of the energy is converted into kinetic energy in the form of wind and waves. The destructive power of an intense tropical cyclone is tremendous, with surface wind speeds near the cyclone center often exceeding 100 kts. Torrential rains falling from the spiral convective cloud bands several hundreds of miles from the center can cause flash flooding and landslides. The storm surge propagating ahead of the cyclone can completely inundate low-lying coastal areas. The combined effects of destructive winds and phenomenal seas can swamp and sink vessels caught in its path. The combination of potentially destructive winds, rains and high seas poses a threat to life and property that cannot be ignored. NOAC Yokosuka resource protection and ASW missions support operations within several major ocean basins for tropical cyclone development, which experience an annual average of 56 tropical cyclones, 72% of the average annual global total of 78 tropical cyclones (reaching tropical storm intensity or greater). The western Northern Pacific basin, which includes the South China Sea (development area), is by far the most active with an annual average of 26 tropical storms and typhoons (33% of average annual global total). Monthly Tropical Cyclone tracks affecting the 7th Fleet region can be found in Appendix B. Essential or favorable conditions must exist for development of tropical cyclone genesis. The major conditions are:

(1) Warm SST (> 78°F)

(2) A pre-existing surface disturbance

(3) Upper level divergence

(4) Lack of vertical wind shear

(5) Coriolis parameter above a minimum value (away from the equator)

Additionally, the structure of a tropical cyclone must have low level inflow, upper level outflow, and movement influenced/affected by synoptic flow at the Level of Non-divergence (LND) measured at the 500 mb level. Climatologic studies have determined areas of favorable development, see figure 5-3.

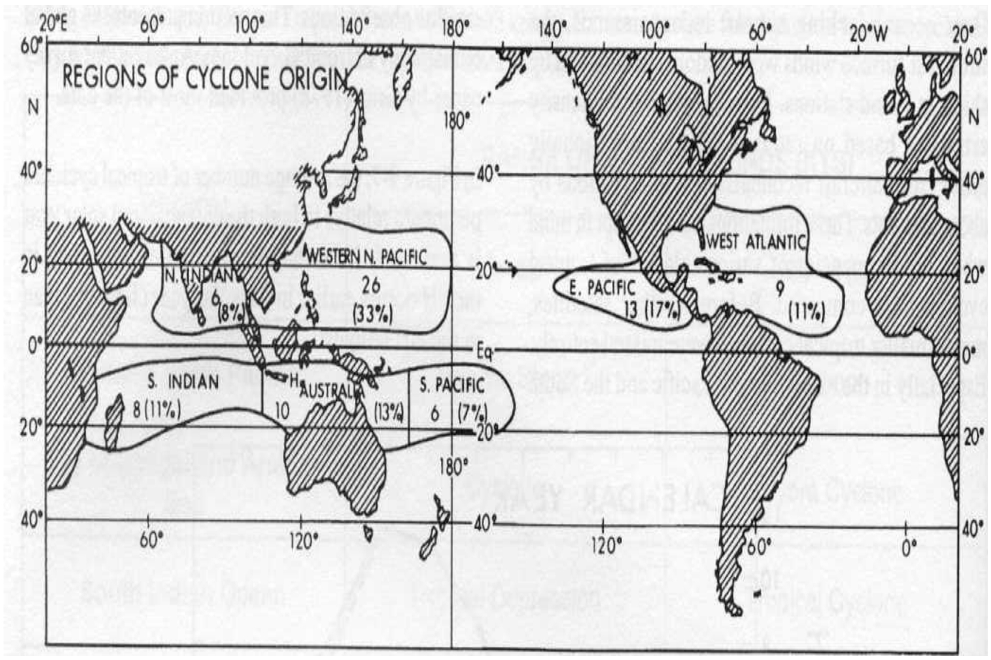

FIGURE 5-3. REGIONS AND PERCENTAGE OF CYCLONIC ORIGIN (TROPICAL CLIMATOLOGY, MCGREGOR AND NIEUWOLT, 1998)

(1) Western North Pacific Ocean. This region experiences more than twice as many tropical cyclones than any other development area and is the only area in which tropical cyclones can occur in any month of the year. August is normally the most active month and 90% of the storm activity occurs during the period of May through December. More than 80% of tropical disturbances that reach depression stage further intensify into tropical storms or typhoons and two-thirds of the tropical storms eventually reach typhoon intensity. Focusing exclusively on the South China Sea, a subset within the region’s data set shows a different pattern. Extrapolating data from the two areas reveals that the South China Sea experiences two maximums in storm formation, the first in May and the second in September. This double maximum is related to the northward and southward oscillation, respectively, of the monsoon trough.

d. Streamline Patterns. Just as important in development of Tropical Cyclones are the seasonal environmental patterns that affect tropical cyclone movement and intensity. It is particularly important in the understanding of tropical cyclones to be able to recognize seasonal streamline patterns for both the surface and upper level flow.

(1) In February, refer to figure 5-4, the winter Subtropical Ridge in the northern hemisphere is located at 25-30° North. Equatorward of the ridge, the northeasterly trade winds heavily influence the northern hemisphere tropics. The general circulations in the eastern and western halves of the Pacific are markedly different. In the western half, the northeasterly trades cross the equator, become northwesterlies, and converge into the South Pacific Convergence Zone (SPCZ) and monsoon trough near 12° south. This flow is known as the Australian summer monsoon. The South Pacific Convergence Zone (SPCZ) lies near 20° South from 175° East to 160° West and is often viewed as an extension of the Australian Monsoon trough but may not always be connected.

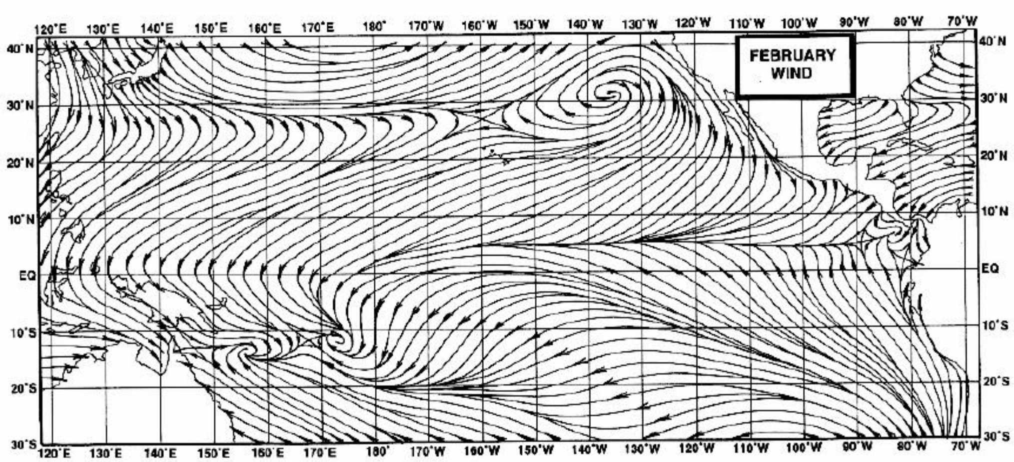

Figure 2.2. Mean surface level streamline analyses over the Pacific for February (Sadler, 1975).

FIGURE 5-4. PACIFIC SURFACE WIND FLOW FOR FEBRUARY

(2) In May the major synoptic features shift northward from the February position, refer to figure 5-5. The northern hemisphere Subtropical Ridge has moved north of 30° North and the ITCZ in the eastern North Pacific is now located near 10° North. The ITCZ in the mid-Pacific becomes a confluence

zone with decreased convective activity and is more commonly referred to as an Equatorial Trough indicating a convergence boundary with very little weather. The ITCZ in the western Pacific is flanked by the SPCZ to the south as it moves equatorward and the near equatorial trough (ET) to the north. A buffer zone begins to appear at 4° North near the Caroline Islands (approximately 150° East). Twin cyclones, one in the northern and one in the southern hemisphere, are common at this time of year.

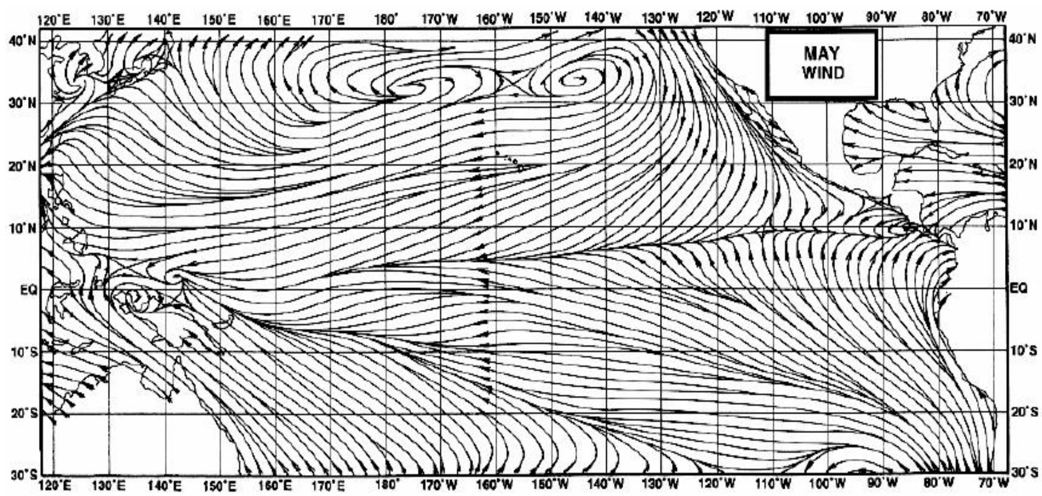

FIGURE 5-5. PACIFIC SURFACE WIND FLOW FOR MAY

(3) By August, the northern hemisphere Subtropical Ridge has migrated to its northern most latitude near 40° North, refer to figure 5.6. Cross-equatorial flow from the southern - hemisphere extends across the entire Pacific, converging into a nearly continuous equatorial trough and monsoon trough in the Northern Hemisphere. The monsoon trough of the western North Pacific is poorly depicted in a long-term mean chart because it is often migratory but it typically displays a southeast-northwest orientation. However, there are instances where the eastern portion of the trough migrates northward, reversing the orientation. Tropical cyclone formation in the western North Pacific is largely confined to the monsoon trough because enhancement of the low level flow on either side of the monsoon trough increases the relative vorticity, divergence, and moisture concentration that makes conditions more favorable to tropical cyclone formation. In the southern hemisphere, southeasterly trades dominate the entire tropical ocean equatorward of the subtropical ridge centered at 25° South. The SPCZ still exists, although it is weak and rarely associated with tropical cyclones.

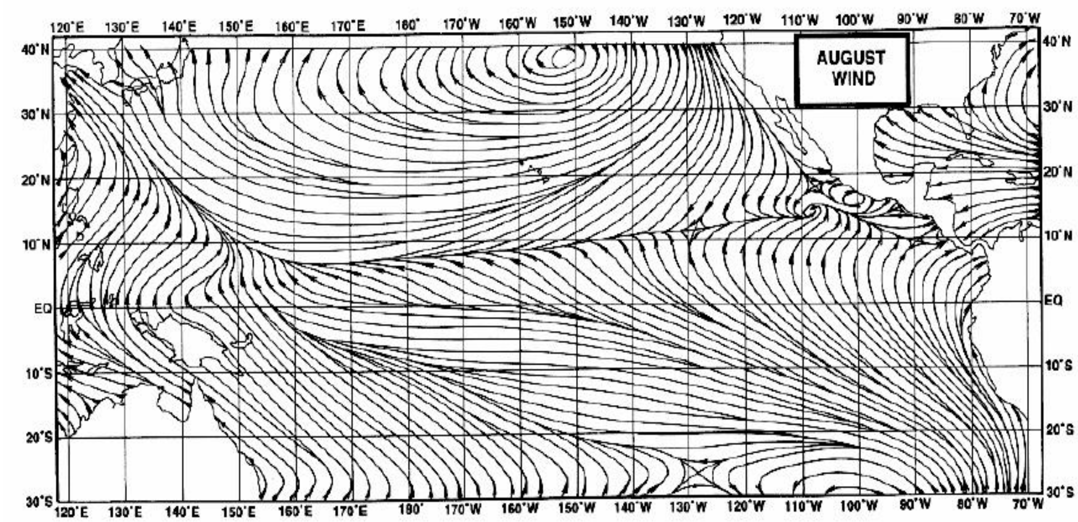

FIGURE 5-6. PACIFIC SURFACE WIND FLOW FOR AUGUST

(4) By November, refer to figure 5-7, the transition season exhibits a general southward movement of the major synoptic features. The monsoon trough extends over the Philippines and Vietnam at or south of 10° North. As in May, the near equatorial trough exists on both sides of the equator in the western Pacific. The SPCZ again becomes more pronounced and linked to the Australian ITCZ. It is during this time that twin cyclones become more apparent as seen near 160° East.

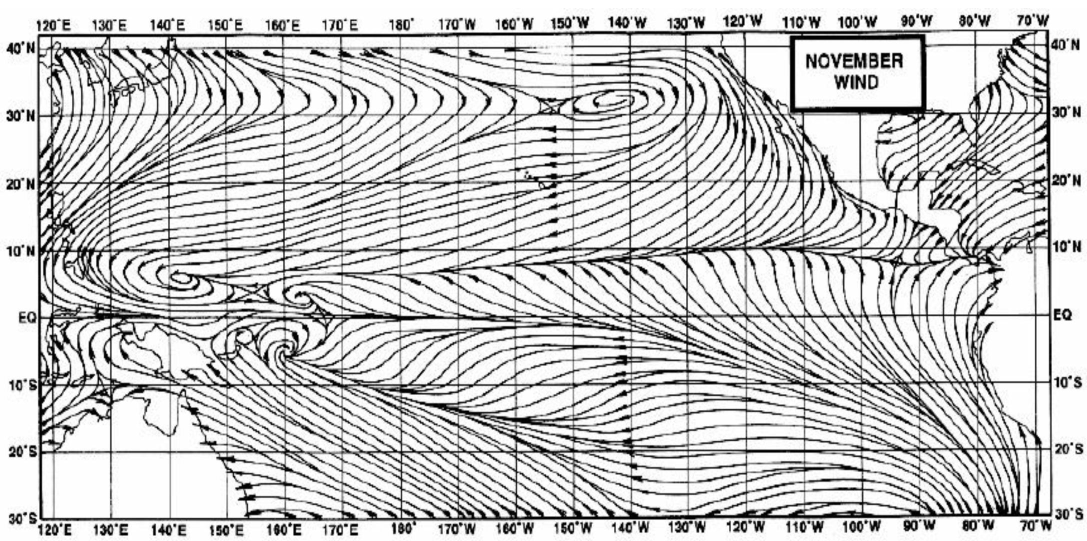

FIGURE 5-7. PACIFIC SURFACE WIND FLOW FOR NOVEMBER

e. Cyclone Motion and Forecast Tracks. The movement of a tropical cyclones (TC) was initially believed to be determined primarily by four major factors: Coriolis parameter (Beta effect); asymmetrical distribution of pressure falls about the cyclone center; integrated steering flow from the surface through the upper troposphere; and interaction with other systems. Additionally, numerous studies have shown that size of the TC affects its propagation relative to its environmental steering and may significantly alter its environment (Carr and Elsberry 1994; Chan and Williams 1987). This inter-dependence of TC track, intensity and size has lead to JTWC to embrace the techniques first studied in the “Systematic and Integrated Approach to Tropical Cyclone Track Forecasting” (Carr and Elsberry 1994) as one of its primary forecasting techniques. The details of the “Systematic Approach” cannot be adequately addressed in this document but a brief overview follows.

(1) The “Systematic Approach” defines a set of conceptual models (TC-environment models) to assist the forecaster in formulating a comprehensive understanding of how the mutual influence of the TC and its environment determines TC motion. There are four tropical cyclone track categories with various types and locations of synoptic features associated with each category of motion:

(a) Straight Runner. TCs embedded in the deep easterly flow equatorward of a continuous mid-level subtropical ridge.

(b) Recurver. TCs that move around the western edge of a mid-level subtropical ridge. The track changes orientation from westward and poleward to eastward and poleward.

(c) North Oriented. TCs embedded in a reverse oriented trough. Low latitude TCs may move eastward before developing a slow, somewhat erratic northward track. Other storm TCs will slow their westward motion and assume a northward track.

(d) Erratic Mover. TCs embedded in weak or aclimatological steering flow.

(2) Examples that fit the systematic approach well are Tropical Upper Tropospheric Trough (TUTT) induced TCs that form near the axis of the subtropical ridge or TCs in the summer that form along the monsoon trough and track to the north or northeast and do not recurve. TCs in the South China Sea are often of this variety.

(3) Dynamic Model interaction and evolution with time are the underlying general principles within the “Systematic Approach.” Conceptual models are organized into three groups:

(a) Environmental Structure: Characterizations of environmental flow, excluding the symmetric circulation of the TC. Two subsets, based on scale, define the environment:

(b) Synoptic Patterns: Large-scale environmental surroundings based on the existence and orientation of various synoptic features, such as cyclones, anticyclones, ridges and troughs.

(c) Synoptic Regions: Smaller areas within synoptic patterns that characterize directions of steering.

Because of the exponential increase in computer power and capability, many new ideas in numerical prediction (data assimilation methods, vortex specification) can be incorporated in the numerical models. Together with an increase in model resolution and better physics, very significant progress has been made in the accuracy of track prediction. However, systematic errors can be identified in some models and statistical post-processing techniques have been proposed to correct for such errors. In addition, major forecast failures continue to occur especially when the track is erratic. Thus, detailed evaluations of model behavior become an important issue. Because every numerical model has its own merits and weaknesses, combining model predictions to give a “consensus” forecast which, theoretically better than any of the individual forecasts, has been adopted by the Joint Typhoon Warning Center and appears to have resulted in a decrease in the overall forecast error. Diagnoses of model behavior has indicated that some model forecasts have large systematic biases under certain synoptic situations. If one can identify such “problems” so that a specific model forecast is removed before all of the model forecasts are combined, the forecasts may be even better. Selective consensus may be of little additional value to the forecasters if the tropical cyclone is not well analyzed in the model or when the model produces erroneous vortices or other systems in the vicinity of a tropical cyclone. The consensus approach in a sense is similar to the idea of ensemble prediction. In the latter, the initial analyses are perturbed to simulate the error distribution associated with errors in the observations and analysis methods. The assumption is that if such a simulation is correct, the envelope of forecasts resulting from each of the perturbed analyses would encompass the true behavior of the atmosphere. Even though such a concept has been applied for daily weather forecasts, its use in the prediction of tropical cyclone motion is in its infancy with varying results. Another major focus has been on applying the concept of potential vorticity tendency to explain the baroclinic behavior of TC motion. Both numerical and observational studies have shown that a TC tends to move towards an area of maximum potential vorticity. This approach can explain track behavior, including track oscillations and some erratic tracks. However, further verification of such a theory is necessary and research into the theory of motion when the TC is interacting with adjacent features (land, terrain, mesoscale convective systems, sea-surface temperature anomalies, etc) should also be carried out.

f. Tropical Cyclone Classifications. NOAC Yokosuka uses standard U.S. definitions with an additional category (Super typhoon) outlined by JTWC:

(1) Maximum sustained 1-minute average surface wind speed in knots:

(a) Tropical depression	25 to 33
(b) Tropical storm	34 to 63
(c) Typhoon	64 to 129
(d) Super typhoon	>129

(2) Note that a one-minute sustained wind average is used as opposed to the ten minute wind average used by WMO International Warning Agencies, to include Japan Meteorology Agency (JMA). When exchanging information with foreign meteorologists, stress the use of maximum sustained winds based on 1-minute average rather than classification terms. Maximum sustained wind speeds provide a common reference for exchange and interpretation of tropical cyclone information. Note that use of one minute sustained wind will result in higher wind speeds as compared to WMO International Warning Agencies such as JMA and the Philippines (PAGASA).

g. Dissipation and Extra-tropical Transition. Tropical cyclones ultimately either dissipate or transform into extra-tropical cyclones. Dissipation is primarily due to two effects. First, interaction with land masses which cut off the surface energy fluxes (in the form of latent heat), and introduce increased frictional effects and disruption to the low-level inflow. Secondly, vertical wind shear which strips away the persistent central clouds and destroys the vertical circulation that is needed to maintain the cyclone's adiabatic process and the transport and exit of mass. Extra-tropical transition is a process where the tropical cyclone moves poleward from the tropics and transforms to an extra-tropical cyclone or causes some form of baroclinic development, such as a wave on a frontal boundary. Surface winds associated with these extra-tropical cyclones may not always weaken, but can equal or exceed those of the tropical cyclone as it transforms into a mid latitude low pressure system. The three types of extra-tropical transitions are:

(1) Complex. A pre-existing front meets a tropical cyclone; a new extra-tropical cyclone is induced on the front as the frontal boundary and cold air wrap around the cyclone with a dry slot initially intruding from the west rapidly wrapping around into the center of the cyclone which then becomes the dominant system. The process makes it appear that the tropical cyclone has been transformed into an extra-tropical cyclone

(2) Compound. A pre-existing extra-tropical cyclone approaches and merges with a tropical cyclone and usurps the tropical vortex. The tropical system appears to have been transformed into an extra-tropical cyclone.

(3) Dissipating. Tropical cyclones can also decay and dissipate over water without first becoming extra-tropical.

2. Tropical Cyclones Affecting Yokosuka. Tropical cyclones affecting Yokosuka generally form in an area bounded by the latitudes 5° North and 30° North, and by the longitudes 120° East and 165° East. The latitudinal boundaries shift poleward during the summer months and equatorward in winter in response to the seasonal changes of the synoptic environment. The great contrast between the cold continental air masses of winter and the warm maritime tropical circulation in summer is the fundamental key to the seasonal changes. In the aforementioned genesis area, typhoons have occurred in all months but, with rare exceptions, those affecting the main Japanese Islands are confined to the period from May to November. Late summer and early autumn are the likeliest seasons for affects to Japan. Size and intensity of the storms vary widely. The majority of cyclones that pose a threat to Yokosuka (any tropical cyclone approaching within 180 NM of Yokosuka is defined as a "threat"

for the purpose of this study) occur from June to October. Tropical cyclones most frequently approach the Yokosuka area from the southwest (nearly 70%). Approach from the south and southeast occurs about 21% of the time, and from the west-northwest the remaining 9%. Tropical cyclones reach their maximum intensity at, or just prior to, the point of recurvature. Most tropical cyclones in the western Pacific recurve between 20° North and 30° North. During the 47-year period from 1945 to 1991, there were 115 tropical storms and typhoons that passed within 180 NM of Yokosuka. Most of these storms had already recurved, were undergoing an extra-tropical process, and were decreasing in intensity.

a. Wind and Topographical Effects. In the months June-October, for the 22 years from 1952-1973, a total of 64 tropical cyclones passed within 180 NM of Yokosuka, or about 3 per year. Tropical cyclone activity within 180 NM of Yokosuka is at a maximum during the months of August and September. Only 20 (31%) of the total 64 tropical cyclones for the period June-October resulted in winds of 34 kts or greater at Yokosuka. Of the 19 tropical cyclones in September, 11 (58%) resulted in winds of 34 kts or greater. Winds in the harbor during the passage of a severe tropical cyclone are greatly influenced by the surrounding topography and the extent of this influence is dictated by the direction of approach of the storm and the passage relative to Yokosuka. From an analysis of tropical cyclone tracks, it is apparent that tropical cyclones that result in gale force winds or greater at Yokosuka can pass to the east or west of Yokosuka. The basic difference between the two passages is the direction of the resultant wind on the harbor.

(1) West. If the tropical cyclone passes to the west of Yokosuka, the wind will generally be from the south. The tropical cyclone must cross the mountain ranges of Honshu. An example of this was Typhoon Nancy (September, 1961) that had a closest point of approach (CPA) of 140 NM west-northwest of Yokosuka. With this storm, there were maximum gusts of 71 kts from the south-southwest, and a sustained wind of approximately 60 knots for a 4-hour period.

(2) East. If the tropical cyclone passes to the east of Yokosuka, the path will be over water and the winds will be generally northerly. An example of this was Typhoon Violet (September, 1996), which had a CPA of 60 NM to the southeast of Yokosuka. As a result of Violet, the harbor experienced gusts of 100 kts from the northwest. SEVENTH Fleet units in port

Yokosuka during the threatening time of Violet reported negligible damage.

b. Wave Action. The port of Yokosuka experiences very little wave action as the result of a typhoon transiting the vicinity. The amount of wave action will vary with the different wind directions and fetch areas if typhoon passes to the west or east of the port. The surrounding land, and the breakwater located near the entrance to Yokosuka Harbor, are major factors in limiting the wave action in the port of Yokosuka. The port of Yokosuka opens into Tokyo Bay in a north-northeast direction for a distance of about 25 NM, so wave action will be greater for a northerly wind (typhoon passage to the east). Yokohama, conversely will experience higher waves from southerly winds.

c. Storm Surge and Tides. Storm surge may be defined as an abnormal rise of the sea along a shore as the results of the winds of a storm and the pressure drop. The piling-up of water on a coast ahead of a tropical storm or typhoon is more apparent in the more dangerous semicircle (the area to the right relative to direction of travel in the northern hemisphere). This is the region of the most intense winds. Yokosuka harbor will be placed in the more dangerous semicircle when a typhoon passes to the west of the area. Storm surge is more pronounced along the south coast of the Japanese Islands to the west of Tokyo Bay. Tokyo Bay opens into the south coast of Honshu. The surge forms to a large extent after entering the inland bays since the width of the continental shelf is generally narrow along the Japanese coast. Most of the surge occurs, therefore, at the inshore side of these bays, neither along the open coasts nor near the mouth of bays. Due to its sheltered position within Tokyo Bay and its location near the entrance, Yokosuka experiences little storm surge. Conversations with the Yokosuka Port operations indicate that a storm surge of about 3 feet has been felt within the harbor with little problem. Surges of this magnitude coupled with the normal tide range of 4-5 feet for the months of June-October do not present any unusual difficulty to vessels, if mooring lines are tended.

3. Tropical Considerations for Sasebo. Sasebo is considered a favorable typhoon haven for most small and medium sized ships. This is mostly due to the protection that the local terrain offers, especially in and around the harbor. The local harbor is protected by mountains on nearly all sides except the west. A typhoon that approaches Kyushu from the east and attempts to cross the island before reaching Sasebo rarely stays intact

during the trip. The local mountains offer such significant protection from typhoons that the illusion of a perfect typhoon haven may be reached. However, Fleet Activities Sasebo has suffered damage from typhoons in the past. The most memorable of such storms was in 1987 when Typhoon Diana damaged sea walls and perimeter fences near the shore line and caused a local ship to pull a 50 ton bollard off the pier and damage its hull. The worst possible scenario for the local area is a storm that approaches from the open waters to the west. Alternate scenarios also exist that could produce heavy chop in India and Juliet Basins and even significant seas in the anchorages of south Sasebo Bay. If an approaching or passing storm is expected to bring gale force winds to the local area for more than 12 hours the following must be considered:

a. If the winds are southerly and a high tide (higher than 9 feet) will occur anytime after the 12 hour point, storm surge conditions should be considered. A true storm surge is extremely rare due to the orientation and tidal range of the local harbor. Even with a high tide of 10 feet, there is still an additional 2 feet before the water level will reach the upper lip of the surrounding sea wall. The danger in this scenario is what is known as the "bathtub affect", and it can occur in India Basin. Reverberation from incoming northward wave trains will reverberate off of berth 5 over the berths 1, 2, 8, and 9. The sloshing of the water can violently bounce ships that are tied up at these berths enough to cause them to break free of their moorings. This was considered to be the contributing factor when the bollard was lifted off the pier in 1987. A reversal of this flow, resulting in a northerly component can also create difficulties for ships that are seeking shelter in the anchorages of south Sasebo Bay.

b. Due to the limited fetch area presented by the elongated north south alignment of the bay, seas inside the harbor rarely rise above 6 feet. However, if northerly gale or storm force winds are present for more than 12 hours, sea heights above 6 feet are possible in the southern portions of Sasebo Bay, in and around the anchorages. This presents a two-fold problem when trying to hold anchor. First the ships are trying to maintain their anchorage in heavy seas, and second they are also being pushed by the strong winds. Many ships in this situation will have to steam against the anchor, just to hold their position.

CHAPTER 6
Yokosuka, Japan

1. Local Geography

a. Kanto Plain. The Kanto Plain, located at the "elbow" where Honshu curves from a north-south orientation to east-west, is Japan’s largest plain. Extending north of Yokosuka, it encompasses 8,100 square miles. It is bordered on the west by the mountains of central Honshu and on the south, east and northeast by the Pacific Ocean. Most of the land in the Kanto Plain is flat low coastal terrain with small, scattered hills.

b. Mountains. The Japanese Islands are so rugged that only one-sixth of the land is arable. The remaining land consists of mountains, forests and pine-covered shorelines. There are three major mountain ranges in Japan. These mountain systems form a series of backbones running through the islands with relatively small plains lying between the mountains and surrounding seas. The principal mountain chain, the Japan Alps, is located in the central section of Honshu, see figure 6-1. These mountains average 5,000 to 12,000 feet in elevation, with Mount Fuji (located 60 miles west of Yokosuka) reaching 12,388 feet (3,776 meters).

FIGURE 6-1. EASTERN HONSHU GEOGRAPHY

c. Miura Peninsula. Yokosuka is located on the eastern side of the Miura Peninsula. This peninsula is hilly, with an average height of 300 feet and highest peak at about 600 feet.

d. Tokyo Bay and Approaches. Tokyo Bay is east of

Yokosuka, oriented in a north-south direction, and is approximately 35 miles in length and 15 miles wide. The approaches to Tokyo Bay are defined as those water areas north of 34.5º N that lead to Tokyo Bay.

2. Seasonal Climate. The seasonal position of the polar front will define the seasons of the Kanto Plain. Intensification of the Asian High during the fall and the winter months causes cool, relatively dry air to be advected over the local area. Autumn is the area's most pleasant season, with mostly clear skies and cool temperatures. Snow flurries occur occasionally during the late winter with little accumulation. The number of days with precipitation and the amount of precipitation increase considerably during the Bai-u and Shurin rainy seasons during the months of June/July and September/October, respectively. Mean temperatures generally follow a smooth curve from month to month. The minimum temperatures occur in January and the maximum temperatures occur in August. The six distinct seasons which occur yearly throughout the Kanto Plain are:

a. Spring Season. The month of March marks the start of the Spring season and a transition from the cold dry winter to the summer rainy season, refer to figure 6-2. Increased heating across the interior regions of China begins to significantly erode the dominance of the Siberian high-pressure system. Low-pressure systems will start forming in interior regions of China where normally the Siberian High dominates. As a result, low-pressure systems begin to track closer to the southern coast of Japan, increasing cloudiness and precipitation over Japan during the spring months. Spring is also the time for sea fog to form and advect over the coastal areas. Sea fog forms as the relatively warmer air cools as it passes over a cooler body of water. Severe thunderstorms are extremely rare in spring but gusty winds are occasionally reported across the Kanto plain.

(1) Synoptic pattern: During transition, the polar front begins its northward migration from south of Iwo Jima and Taiwan to near the southern coast of Honshu. As the Asian continent begins to warm up, the Siberian High weakens and moves northwestward and the frequency of polar outbreaks decreases. Occasionally, bubble (migratory, dynamic) highs break off the Siberian High and move eastward across the Sea of Japan and central Honshu, Hokkaido, or Sakhalin Island. During May, weak thermal lows begin to appear over northeast Manchuria and China. The mid-Pacific High begins to intensify and move northwestward. Tropical easterlies also move north in response to the increased incoming solar radiation. The Sea of Okhotsk low retrogrades to

a position over northern Mongolia and the Aleutian low weakens. Migratory lows along the polar front, which remain south of Honshu during the winter, now track much closer to Honshu.

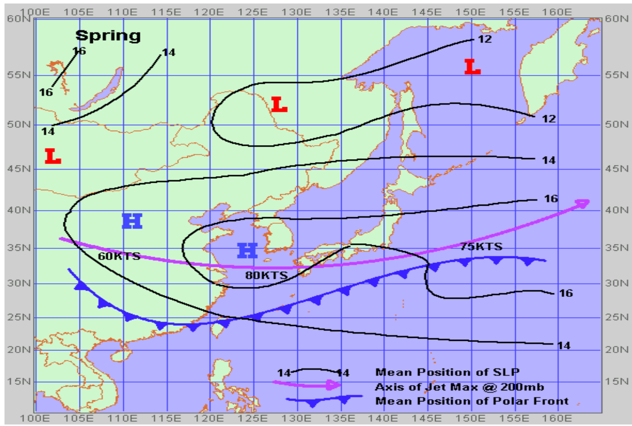

FIGURE 6-2. SYNOPTIC PICTURE OF SPRING: MID-MARCH THROUGH MID-JUNE

(2) Cloudiness and weather: The most significant weather producers during Spring are the migratory lows moving eastward along the front. The lows initially become evident in the Taiwan area and move northeast along the front producing a warm, moist, southeasterly flow over Honshu at the surface and aloft (850 and 700mb). This southeasterly flow increases cloudiness and precipitation, which lasts from 12 to 24 hours over central Japan. Increased cloudiness is associated with more frequent appearances of migratory lows. Cloud cover generally ranges from an average of 5/8ths in April to 7/8ths by the middle of June. As lows pass south of Honshu, expect a broad area of thick clouds and heavy precipitation. Very low ceilings, 800 to 1,000 feet, and poor visibilities, 1 to 3 miles, are common near these lows. Tops may extend from 15,000 to 25,000 feet. During early to mid-June, adverse weather becomes more persistent with stratocumulus layers lowering ceilings for several days as the polar front approaches the area.

(3) Precipitation/obstructions to vision: Precipitation also increases during the Spring, averaging 13 to 16 days per month. Rainfall averages from 4.90 inches in March to 8.50 inches in June. This increased precipitation is a result of the northward migration of the polar front and the attendant warm frontal type weather (overrunning of mT air over modified mP air). Thunderstorms during this time of the year are infrequent, gradually increasing throughout the spring months

from an average of 0.3 thunderstorm days in March to 1.1 thunderstorm days in June. Fog and haze become a forecasting challenge as the occurrence of IFR conditions become more frequent.

(4) Wind: A sea breeze circulation produced by the formation of diurnal low pressure centers over southeastern Honshu cause wind direction to become more southerly during the afternoon hours. Winds will maintain northerly component from evening through midday. Gusty low level winds frequently accompany the eastward migratory lows along the polar front and 20 to 30 kt winds are common. The jet stream weakens considerably and moves northward to northern Japan during the spring season. Two branches often will occur, one over northern Japan and one over southern Honshu. The average wind speed of the jet during the spring season is 80 kts.

(5) Temperature and humidity: Average maximum temperatures increase throughout the spring, from 54° F in March to 75° F in June. Average minimum temperatures show the same trend with 41° F in March to 65° F in June. Humidity increases during the late spring to an average of 75%.

b. Bai-u Season. The Bai-u season, refer to figure 6-3, usually begins in the middle of June and continues until the middle of July. Many Japanese say that the Bai-u begins and ends with a thunderstorm. The Bai-u season is characterized by the polar front lying east-west along the southern coast of Honshu during June. During July, the polar front oscillates from south of the local area to over northern Honshu. During this period, the polar front becomes the most dominant weather feature affecting local weather.

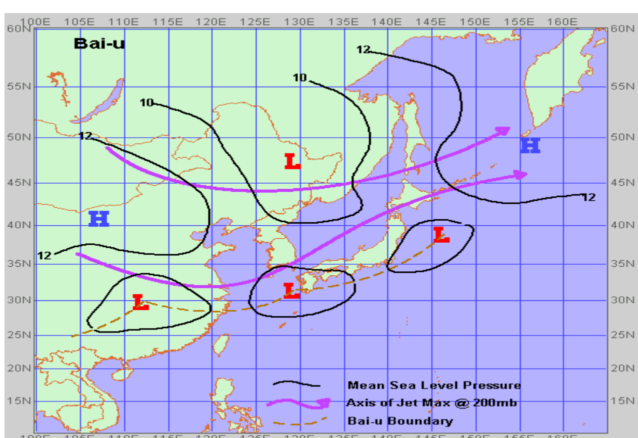

FIGURE 6-3. SYNOPTIC PICTURE OF BAI-U: MID-JUNE THROUGH MID-JULY

(1) Synoptic pattern: The most significant synoptic pattern is that the Bai-u boundary is located between the western Pacific High and the Sea of Okhotsk High. During this time, a large low-pressure area develops across Manchuria and Yangtze River region. At the 500mb level, the Sea of Okhotsk High is depicted as a cut-off high (blocking high) and the continental low is depicted as a cut-off low. The blocking feature is one of the main causes of development of the Bai-u boundary across the Kanto plain. In addition, the jet stream pattern follows closely around the blocking features, with the northern branch of the jet stream flowing north of Manchuria into Kamchatka and the southern branch flowing south of Japan northeastward, then merging with the northern branch over the northwest Pacific. The Sea of Okhotsk High is cold core, generating low-level northeasterly winds across northern Japan and advecting mP air westward. The Sea of Okhotsk High may become a dynamic feature and migrate southwestward across the Sea of Japan or it may become part of a southern branch over eastern Siberia or the Bering Sea. During Bai-u season, the western Pacific High moves northwestward and centers south of Japan in the vicinity of Bonin Island as the western Pacific subtropical ridge. This allows west to southwest winds south of Japan to bring warm, mT air northward around the western edge of the ridge. The Bai-u front lies between the two high-pressure centers and their associated air masses (mT and mP). The front extends from the coast of China near 30° N latitude, eastward along the southern coast of Japan, and into the central Pacific. A series of low-pressure centers generate along the front. These weak lows form in the East China Sea and generally move rapidly eastward under zonal flow with little intensification. In some years, these weak lows move too quickly along the Bai-u boundary across the Kanto plain to produce any measurable precipitation. When that occurs, the Japanese call this the Kara Tsuyu, or a dry rainy season. The southern branch of jet stream intensifies the Bai-u boundary and when this southern branch starts migrating north, the Bai-u season ends. Overrunning occurs when the subtropical ridge forces warm, moist air northward over the cooler air north of the Bai-u boundary. This scenario resembles weather found in advance of a warm front. The slope of the front results in the effects of the overrunning occurring as much as 200 miles north of the surface front. Wind flow aloft is a strong controlling factor of the Bai-u front. Short-wave troughs and other minor impulses, discernible on satellite charts, cause waves to form along the front and generate downstream cyclogenesis. Generally, after a major low passes east of the local area, the Bai-u pattern will become established with mP high pressure to

the north, and the subtropical ridge to the south of southern Honshu. In addition to the lows forming in the East China Sea, a series of small perturbations form along the front near Kyushu and Shikoku. These lows move toward the Kanto plain every 2 to 3 days, producing periods of intermittent or steady rain and fog. At times, the front seemingly dissipates to the south and reforms to the north without any precautions. If a typhoon develops and moves toward Japan during the Bai-u season, precipitation intensity increases temporarily in advance of the developing subtropical ridge and ahead of the leading edge of the typhoon. Often times, a baroclinic leaf develops across Japan and the Sea of Japan. After a typhoon passes the local region, the western Pacific subtropical ridge significantly expands behind the remnants of the tropical system, pushing the Bai-u boundary north, causing fair weather across the Kanto plain. Sometimes this expanding high removes the Bai-u boundary completely.

(2) Cloudiness and weather: Overrunning of mT air over mP air causes unfavorable weather to extend far to the north of the frontal boundary. When the front lies south of Yokosuka, expected conditions are those of typical warm frontal weather with poor visibilities in precipitation and fog, and low ceilings of stratus and stratocumulus clouds. South of the front, mT air mass weather is predominant. When the front moves north of Yokosuka, cumulus type clouds become prevalent.

(3) Precipitation: The overrunning described earlier results in extended periods of precipitation occurring along the frontal zone. In June, rain and drizzle occur at an average of 19 days decreasing slightly to 17 days in July. The amount of precipitation will vary directly with the intensity of the Sea of Okhotsk High. The more intense the High, the more active the front becomes. Precipitation ranges from an average of 8.7 inches in June to 5.7 inches in July.

(4) Wind: The predominant wind direction is southerly with northwest to northeast winds indicating rain, drizzle and fog. A shift to the southwest indicates the possible formation of a small low over Honshu with rain showers embedded in the stratiform clouds. There is a definite sea breeze during the day. An increasing southerly flow during the day increases the chance of rain showers at night. This is particularly true in the mountainous regions. By July, the jet stream has weakened considerably and migrated northward. Wind speeds decrease to 50 to 60 kts with the jet core located between 40,000 and 45,000 feet over northern Honshu and Hokkaido.

(5) Temperature and Humidity: Temperatures slowly begin to increase. The Kanto plain remains relatively cool as it continues under the influence of modified mP air mass. Relative humidity is high, averaging about 88% for June (up from 78% in May). The highest humidity, often 90% or greater, occurs between the hours of 2200 and 0600 local.

c. Summer. The end of the rainy season marks the beginning of summer for Yokosuka, lasting from mid-July through mid-September, refer to figure 6-4. The western Pacific subtropical ridge builds, and warm, moist mT air flows around the western edge of the high pressure with the Asian summer monsoon dominating the weather in the mid-latitudes and Japan.

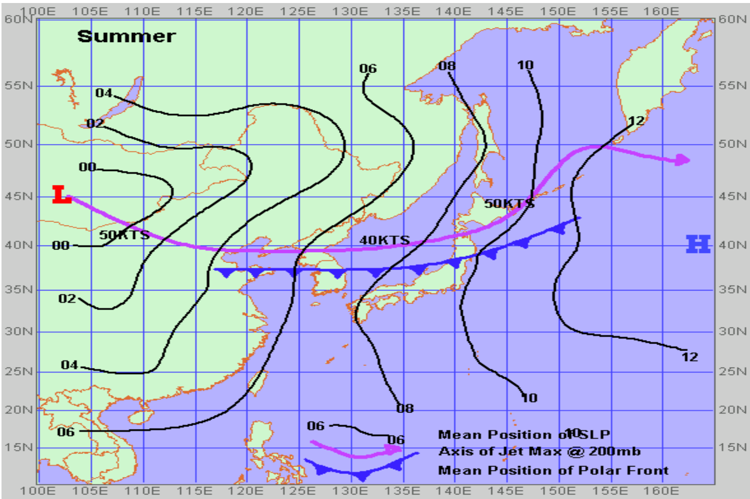

FIGURE 6-4. SYNOPTIC PICTURE OF SUMMER: MID-JULY THROUGH MID-SEPTEMBER

(1) Synoptic pattern: The Siberian High weakens considerably and a seasonal low (Monsoon Vortex) becomes dominant in the interior of China with the Bai-u boundary migrating north out of the Kanto plain, as it extends from Hokkaido westward into Manchuria. By August, the boundary lies over Sakhalin Island and southern Mongolia. The migratory lows forming along the boundary are very weak and affect only northern Honshu and Hokkaido. Occasionally, the polar front reforms south of the local area (southeastern Honshu) when the air mass to the north is modified. In this case, a secondary low forms near Shikoku or Kyushu in response to an upper level trough forming in the Yellow Sea. This low then follows an eastward track across the Sea of Japan. When this occurs, the accompanying precipitation will be similar to the Bai-u type

season.

(2) Cloudiness and weather: Cumuliform clouds associated with mT air are predominant over the local area. The east coast of Japan is now the windward side with northward flowing air lifted orographically by the mountains to the west of Yokosuka. Typically once the summer pattern is established, convective clouds develop by mid-morning and increase during the early afternoon with showers or thunderstorms developing by late afternoon or evening hours. These showers are usually confined to the mountains west of Yokosuka and over the northern Kanto Plain. A forecast of shower activity in the vicinity of Yokosuka generally occurs over the Yokohama, Camp Zama, and Camp Fuji regions. Usually, the cloud conditions, showers, and thunderstorms dissipate rapidly during the late evening hours.

(3) Precipitation: A change in the predominant cloud type (cumulus vice stratus or stratocumulus), with a change in the type of precipitation (showers vice steady precipitation), decreases the amount of precipitation after the Bai-u season. The summertime average is approximately 5.5 inches, falling mostly as showers. Thunderstorms increase during the summer months with an average of 1.7 storms occurring in August, the month of maximum occurrence.

(4) Winds: Winds are generally light and variable during the early morning hours, increasing to an average of 7 to 10 knots from the south or southwest during the afternoon hours. The jet stream migrates to a mean position over eastern China at altitudes from 35,000 to 40,000 feet and wind speed around 50 kts.

(5) Temperatures and humidity: As the rainy season ends the maximum temperature increases rapidly. The prevailing southerly flow of mT air over the Kanto Plain region results in warm temperatures and high humidity, making the summer somewhat oppressive. Due to the cooling effect of the sea breeze, however, Yokosuka reports daytime temperatures frequently lower than those recorded farther inland. August will normally produce the highest temperatures with humidity values often in excess of 80%. When the strong subtropical ridge predominates the Kanto plain, extreme temperatures occur.

d. Fall Shurin. In early September, the polar front begins its migration southward, reaching the Kanto plain and southeastern Honshu by mid-September, refer to figure 6-5. The Kanto plain at this time experiences a fall rainy season which the Japanese call the Shurin, meaning autumnal light rain. The Shurin does not always occur every year, but if formed, it is generally short lived in comparison to the Bai-u season, lasting about two weeks.

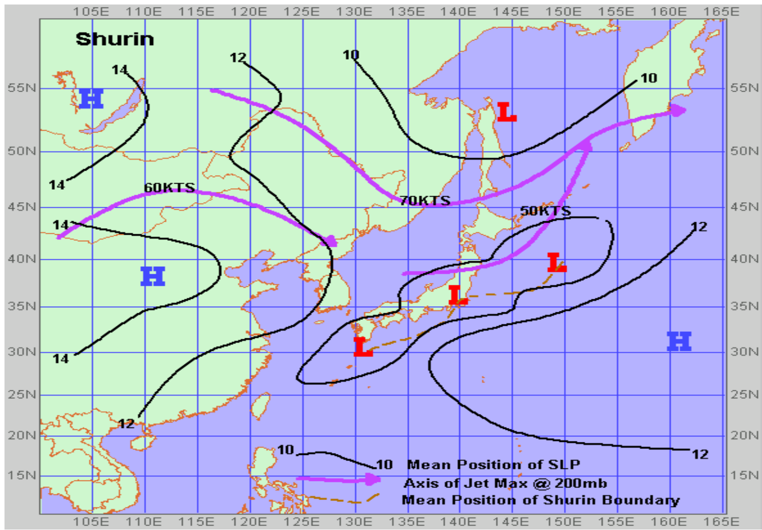

FIGURE 6-5. SYNOPTIC PICTURE OF SHURIN: MID-SEPTEMBER THROUGH MID-OCTOBER

(1) Synoptic pattern: As the polar front slowly moves southward, it is easily recognized in satellite pictures by a wide band of cloudiness. When the front lies to the south of Honshu, weather is characterized by cloudy skies with low ceilings and visibility. The 850mb thermal analysis also will show the front south of Yokosuka, with thermal packing over the area. The cP air mass in Siberia is not yet strong enough to produce anything except weak extra-tropical lows and associated weak cold fronts. The Siberian High begins to build, and by mid-October, center pressure values will exceed 1025mb. The warm core Pacific High begins to weaken and recede to the southeast. A quasi-stationary low-pressure center forms in the Sea of Okhotsk, spawning short-wave troughs in the Sea of Japan. With the polar front transiting south of Japan, the Kanto plain and most of Japan comes under the influence of cooler air originating over Siberia.

(2) Cloudiness and weather: Cloudiness and precipitation increase during the Shurin with warm frontal clouds and rain occurring across the Kanto plain. Extensive mid to high-level clouds occur both sides of the front. South of the polar front, conditions remain similar to that of the summer monsoon. The frequency of fog and haze increases during the Shurin period.

Lower visibilities are also produced by subsidence associated with migratory high-pressure systems.

(3) Precipitation: With the polar front over the local area and the migratory lows moving eastward from the Shanghai area, the frequency of precipitation during September and early October increases to an average of 18 days. Prior to the onset of the Shurin, most of the precipitation is in the form of showers. As the polar front transits south of southeastern Honshu, precipitation takes the form of steady rain or drizzle with prevailing stratiform clouds. Thunderstorms continue to occur, primarily over the mountains west of Yokosuka and the northern Kanto plain.

(4) Winds: The prevailing wind direction changes from south-southwest to north during the Shurin. This trend continues through October with southerly winds occurring less than 10% of the time. A short duration of sea breeze with a return of northerly winds after sunset is common. The jet stream begins to intensify but remains over northern Japan. Two branches of jet become evident. A northern branch extending from Vladivostok to southern Hokkaido at 40,000 feet with wind speeds of 60 to 70 kts, and a southern branch which flows across Korea eastward into the Tokyo area at 40,000 feet with speed of 70 kts. By October, the northern branch dips southward and extends from northern Korea into southern Hokkaido at 38,000 feet with speeds of 80 kts. The southern branch extends from the Shanghai area into southern Honshu at 45,000 feet with speeds of 90 kts.

(5) Temperature and humidity: As the polar front moves south of the local area, both temperatures and relative humidity begin to decrease.

e. Fall. Fall is the transition period between the warm humid summer season and the cold dry winter. The predominant tropical cloudy weather of summer time is replaced by colder, drier, and less cloudy conditions. The primary weather producers during this period are cold frontal systems from the Asian mainland,refer to figure 6-6. On average, one frontal passage per week can be expected. A typical frontal passage is preceded by increasing mid to high cloudiness with light rain and very isolated thunderstorms. Following frontal passage, mostly clear skies can be expected for three or four days. During this clear period, it is very likely for morning fog to form due to radiation cooling.

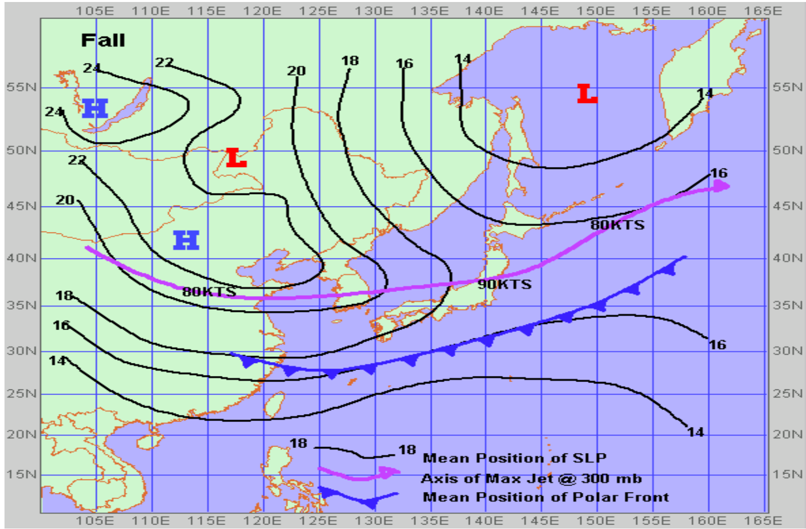

FIGURE 6-6. SYNOPTIC PICTURE OF FALL: MID-OCTOBER THROUGH NOVEMBER

(1) Synoptic pattern: From mid-October through November, the polar air of the northern latitudes forces the polar front well to the south of Japan and cooler, dryer air covers most of Japan. The Siberian High becomes the dominant feature over the Far East. High-pressure cells often break off from the Siberian High and move across the Kanto plain. During this period, the Sea of Okhotsk Low continues to develop. The cP air, after it leaves the Asian mainland, is modified somewhat as it crosses the Sea of Japan. As it descends the eastern slope of the Japanese Alps, the air is warmed adiabatically. It is for these reasons that southeastern Honshu does not experience extremely cold temperatures and why frost does not occur in the Kanto plain until mid-November. As migratory highs slowly move across Honshu from mid-October through December, several weeks of extremely fine summer-like days occur in the local area which the Japanese call Ko-Haru or little spring.

(2) Cloudiness and weather: Cloudiness decreases significantly during the fall with partly cloudy skies prevailing by November. Cloudy skies, if any, are usually associated with an approaching cyclonic disturbance, an approaching upper level trough, or with migratory lows moving north of the Kanto plain. These cyclonic circulations produce a cool, moist, northeasterly, low-level flow.

(3) Precipitation: The amount of precipitation decreases after the polar front moves well to the south of the area. Morning fog and afternoon haze can affect visibility

during late October. As the fall season progresses, the likelihood of fog will decrease as the occurrence of haze will increase. Freezing temperatures and some snow can be expected in the extreme northern part of Honshu. Freezing temperatures and snow, although they do occur occasionally, are rare in the Kanto plain during the fall season.

(4) Winds: Northerly winds with average speed of 10 kts during the fall season. Strong winds may occur when a strong high-pressure system is located over the Asian continent and the Sea of Japan area while an intense cyclonic disturbance is located east to northeast of Honshu with a trailing cold front extending south of Honshu. The jet stream, which continues to intensify, becomes firmly established and begins moving southward to a mean position over central Japan. The northern branch passes over North Korea at 35,000 feet and averages 100 kts. The southern branch crosses central China at 40,000 feet at 120 kts and merges with the northern branch over central Honshu.

(5) Temperature: Temperatures begin to decrease appreciably, dropping from an average of 73° F in September to 55° F by November.

f. Winter. Winter is controlled by the large Siberian high-pressure system, which results in predominantly cold, dry northwesterly winds over Japan. About every four to five days, a trough will move through the region bringing cloudiness and light precipitation, mostly rain and rarely snow, refer to figure 6-7.

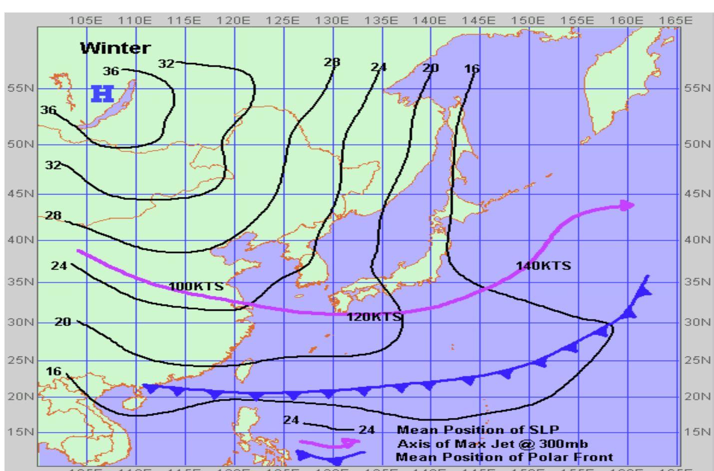

FIGURE 6-7. SYNOPTIC PICTURE OF WINTER: DECEMBER THROUGH MID-MARCH

(1) Synoptic pattern: From December through mid-March, Japan is under the influence of cP air moving eastward from the Asian continent across the Sea of Japan. Surges of cold air, which are essentially dynamic highs breaking off the Siberian High, follow strong cold fronts across Japan. The Siberian High is at its maximum intensity during January and February while the western edge of the mid-Pacific High is weak and has receded to the southeast. The polar front lies between these two high-pressure areas. A semi-permanent low develops in the Sea of Okhotsk during the winter and provides an anchorage for a semi-permanent trough extending into the Sea of Japan. The temperature difference between the cold Asian land mass and the warmer waters of the Sea of Japan produce this trough. Generally, the lows affecting the Kanto plain are those that develop in the Yellow Sea, Shanghai, and Taiwan; with the Shanghai and Taiwan systems being the most frequent.

(2) Cloudiness and weather: Cloud cover is extensive over the Sea of Japan, the western coast of Japan, northern Japan and the windward slopes (western) of the mountains of central Honshu. The Japanese Alps of central Honshu provide an excellent cloud barrier, and areas to the east of the mountains experience many fine wintry days with much less cloud cover than the western coastal areas.

(3) Precipitation: A northwesterly wind flow picks up moisture over the Sea of Japan and lifts it orographically over mountainous terrain, producing frequent snowfalls over northern Japan and the west coast of Japan. In towns near the Sea of Japan, snow lies 3 to 4 feet deep for weeks, and drifts to a depth of 15 to 18 feet occur in the valleys. The location on the leeside of the mountains spares the Kanto plain of much of this weather. In the Kanto plain, snowfall occurs on the average of two or three days during January and February, and some years with no snow at all.

(4) Winds: Northerly winds averaging 10-15 kts are predominant during the winter months. Wind flow from the northwest through north at all levels will normally produce mostly clear skies. Aloft, the jet stream reaches its southern most position. The two main branches of the jet stream merge into a main core immediately to the west of Japan. The northern branch fluctuates in intensity and position, while the southern branch remains relatively stable. At the junction of the two jet branches, daily variations in wind speed are considerable with winds of 120-150 kts between 25,000 and 40,000 feet common.

(5) Temperatures and humidity: While very cold temperatures prevail over Manchuria, this cP air becomes considerably modified as it moves across the Sea of Japan and reaches central Honshu. High temperatures are in the lower 50s F with low temperatures in the high 30s F. Following frontal passages and fresh outbreaks of polar air, the daily maximum and minimum temperatures will be lower than normal. Humidity decreases to a comfortable level with an average of 64%.

CHAPTER 7.
Sasebo, Japan

1. Local Geography. The physical geography of Japan includes four main islands and two island chains, Kyushu being the southernmost of the main islands. Sasebo is physically located on the west coast of Kyushu, 30 NM north of Nagasaki and 120 NM southeast of the Korean Peninsula (33.16 N, 129.72 E), see figure 7-1. Kyushu is bordered on the southeast by the North Pacific Ocean, on the west by the East China Sea, and on its northwest side by the Korea Strait. The Tsushima and Korea Straits combined make up the connecting body of water between the East China Sea and the Sea of Japan. Kyushu is separated from the Japanese islands of Shikoku and the main island of Honshu by the Inland Sea. The rugged mountains of Kyushu extend from north to south through the center of the island with maximum elevations near 3000 feet. Sasebo Harbor is well protected by hills and mountains on all sides. This protection is particularly evident within Sasebo Bay, where hills as high as 787 feet sit within 1 NM of the harbor.

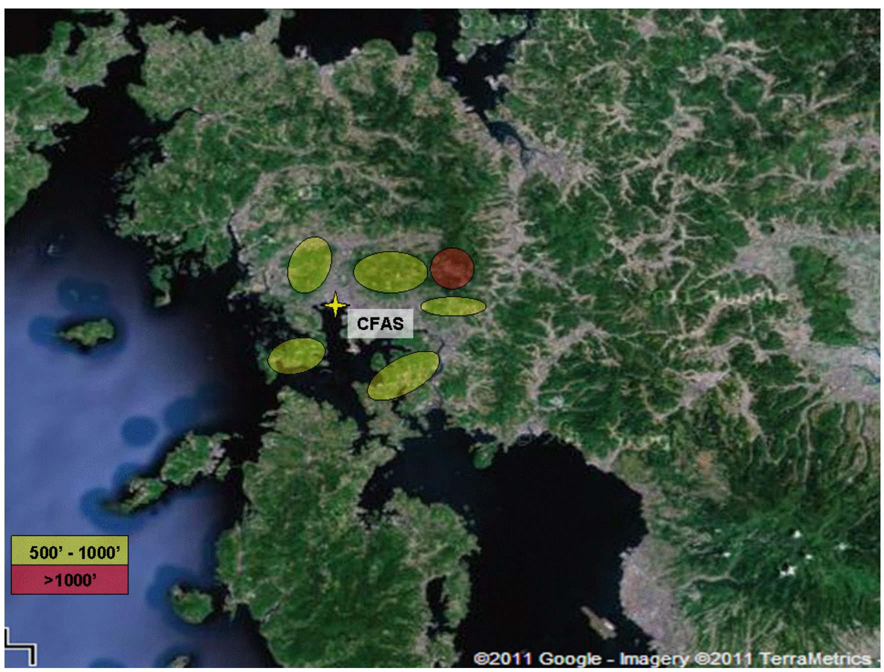

FIGURE 7-1. SASEBO BAY GEOGRAPHY ON KYUSHU

a. Ryuku Islands. The Ryukyu Island Chain forms a 750 NM arc of islands stretching from the southern tip of Kyushu to the northernmost tip of Taiwan (also known as Formosa and the first island chain). In stark contrast to Northern Kyushu, these islands experience tropical weather year round. Okinawa is located in the center of this chain, which forms a natural boundary between the East China Sea to the west and the Philippine Sea to the east.

b. Korea and Tsushima Straits. The Korea and Tsushima Straits separate the southern coast of Korea and northwest coast of Kyushu. The straits are bound on the northeast by the Sea of Japan and the southwest by the Yellow sea. In addition, they are divided into a west and east channel by Tsushima Island. West being the Korea Strait and the east channel being the Tsushima Strait. The straits are approximately 150 NM in length and vary in width from 27 to 110 NM wide.

c. Korean Peninsula. Northwest of Kyushu is the Korean peninsula which separates the East China and Yellow Seas from the larger Sea of Japan. The peninsula itself is consists of a mountain range that runs the length of the peninsula down its eastern side. These mountains vary in height from 3,000 to 6,000 feet, with elevations gradually decreasing westward toward the Yellow Sea and southward toward the East China Sea.

2. Seasonal Climate. The weather in Sasebo has been compared to Norfolk, Virginia. Summers are hot and humid with an average temperature of 85°F. Winters are cold and dry, with occasional periods of snow showers. Typhoon season runs from mid-June through late October. Sasebo will typically see 4 to 5 typhoons per year. Appendix D depicts station climatological conditions.

a. Spring. Spring is marked by mild, comfortable weather conditions. Light northeasterly to easterly winds prevail as the subtropical ridge begins to move north. [The mean position of the polar front boundary lies just south of Kyushu throughout most of this season. Occasionally, the frontal boundary will drift over northern Kyushu causing extended periods of rain and occasional thunderstorms.] Average temperatures range from 47°F in March to 63°F in May. [During this transition period, the models tend to have a hard time with placement and strength of systems.] Careful synoptic analysis is a must for accurate forecasting during this season.

(1) Cloudiness and weather. The beginning of the season is marked by good visibility and partly cloudy skies. Occasional moderate to strong polar outbreaks can still produce snow showers over the local area well into the month of March, and even into the first week of April on rare occasions. By June, the average daily humidity begins to increase, leading to periods of morning fog and afternoon haze. On rare occasions,

usually the morning after a heavy rain, thick fog will form over Sasebo Bay and reduce visibility to less than 1/2 nautical mile. Winds greater than 20 kts for any reasonable period of time will clear the air enough to inhibit haze and fog for approximately 24 to 36 hours. The instability associated with an approaching frontal system will have the same effect. Percentage of cloud coverage gradually increases into June, leading up to the rainy season. Thunderstorm activity is at a minimum early in the season with little to no activity. However, with the approach of the rainy season, thunderstorms can become an almost daily phenomenon. When the moist tropical frontal boundary of the rainy season sets up over Kyushu, thunderstorms and periods of heavy rain can be expected along the active portion of the frontal boundary. If the frontal boundary lies over the Korean Straits or northwestern Kyushu, diurnal thunderstorms will occur between 0300 and 0500 daily. The only noted exception to this rule is that when heavy rain of four inches or more over 24 hours occurs for 2 days or more in a row. Then the amount of fresh water entering the bay will cool the local offshore water temperatures enough to minimize the land-sea interface temperature difference that acts as the catalyst for local thunderstorm activity. If the frontal boundary moves into the Yellow Sea or south of Sasebo, no thunderstorm activity should be anticipated. The frontal boundary provides the extra instability needed to produce thunderstorms over the local area. Without it, divergence from the subtropical ridge tends to cap any vertical development of moisture laden clouds.

(2) Precipitation. In March and early April, some of the precipitation can still be in the form of snow. By the end of April, all precipitation is liquid in form. The precipitation totals rise slightly from those seen in the winter with an average of 7 inches in April and 7.42 in May. This is only a net increase of about 2 inches in the monthly average. By the end of May, the local area will receive about one day of rain per week. This slowly increases leading up to the rainy season in late June. By the first and second week of June, episodes of rain and rain shower activity may occur for 2 to 3 days at a time as tropical moisture slowly begins to move into the local area.

(3) Winds. The average wind speed during the spring season runs about 5 to 10 kts. The average wind direction is easterly early in the season, gradually becoming southeast by the beginning of the rainy season. Outside of any significant synoptic event, the average daily wind regime will consist of light and variable winds overnight with the winds increasing to

8-12 kts during the afternoon hours with the onset of the sea breeze. Spring is marked by a slight increase in wind and thunderstorm advisories. On average, 3-5 small craft advisories and 1-3 gale advisories occur per month. During a strong, but slow moving frontal boundary, southerly winds have been known to increase to storm force, locally, over the open waters of Sasebo Bay. This is a significant factor for local forecasts as Fleet Activities Sasebo is located at the extreme north end of this bay.

(4) Temperature and humidity. Early in the season, daily temperatures are mild with low average humidity levels. Daily highs can be expected to reach the mid to upper 60s F with the lows still dipping into the upper 40s F and lower 50s F. The relative humidity early in the season remains comfortably low averaging 40-70%. By the end of the season the average humidity levels increase to 70-90%. Daily highs by late spring are up to the low 80s with lows in the 70s F. By the end of the season, rink of heat stress increases during several hours of red flag conditions in the afternoons and yellow and green conditions overnight. In extreme cases, during a dryer than normal season, the temperatures will increase to near 90° F, during the day. The frequent periods of rain that are normally experienced here tend to moderate the daily temperatures. In a dry season, the absence of this rain will allow the daily temperatures to become hot and uncomfortable very early in the season.

b. Rainy Season. The rainy season begins in early June and lasts through mid-July. A marked increase in clouds, precipitation, and humidity are noted during this time. The average rainfall amount jumps from 7.42 inches in May to over 12 inches in both June and July. This is a direct result of the polar front boundary slowly moving north past Kyushu. During this time, the frontal boundary will actually sit over northern Kyushu for days at a time. Average temperatures range from 70°F in June to 76°F in July. Heat stress quickly becomes a factor as the average humidity slowly rises above 70%.

(1) Cloudiness and weather. The rainy season is marked by broken to overcast conditions and periods of moderate to heavy rain showers. Most of the precipitation of this regime is in the form of showers. However, an approaching warm front will produce periods of steady or intermittent rain over the local area. The warm, moist air that moves into the area during this season tends to be very unstable, often producing violent thunderstorms over the local mountains. As the polar front

boundary migrates northward and passes through Kyushu and the Korean straits, expect periods of extended precipitation that could last for days at a time. When the frontal boundary lies over the Tsushima strait, rain showers and thunderstorms can be expected in the local area. This type of weather will persist until the frontal boundary moves north of the Korean Straits or South of Nagasaki. A third scenario for showers exists when the subtropical ridge shifts northward and a pronounced surface ridge develops in the East China Sea. This usually occurs late in the season and is a good sign that the rainy season is on its way out.

(2) Precipitation. As mentioned above, the rainy season brings a remarkable increase in precipitation to the local area. All precipitation during this season is in liquid form and predominately showery in nature. It is not uncommon to receive 2 or 3 inches of rain in a 24 hour period during this time of the year. On some occasions up to 5 inches can fall in one 24 hour period. Such a large amount of precipitation all at once is considered severe in nature due to local area affects.

(3) Winds. The wind direction is predominantly southeasterly early in the season, gradually shifting south then southwest by the end of the season. The average wind speed is 4 to 6 knots. Outside any major synoptic regime, the winds will average up to 8-12 kts with gusts to 20 kts during the day with the onset of the sea breeze and decrease to less than 6 kts overnight.

(4) Temperature and humidity. The average temperatures during the rainy season jump 7°F to an average daily temperature of 70°F near the beginning of the season in June. The average daily humidity also rises dramatically from 40-50% during the Spring months to above 70% during the rainy season. It is at this point that heat stress slowly becomes a significant daily factor. As the season changes, frequent periods of red flag conditions are expected by the end of the season.

c. Summer. The summer season is marked by high temperatures and high humidity levels. Air mass thunderstorms are common in the evenings as cooler air from the land moves over the warmer bay waters. This is also the most active period for tropical cyclone impacts as they tend to recurve up into this area, after forming in the Philippine Sea near Guam. Precipitation is down from 12 inches per month during the rainy season to only 8 inches per month in summer. The average temperature increases to a peak of 80°F with heat stress conditions remaining in the yellow and red categories, occasionally drifting into black.

(1) Cloudiness and weather. Haze is the predominant local weather phenomenon that occurs during the summer season. As the subtropical high moves north, the ridge axis sets up over northwestern Kyushu producing light winds and fair skies. Light winds, combined with the high humidity of the tropical summers, is the perfect catalyst for the hazy conditions that are present throughout most of the summer. Air mass thunderstorms are also prevalent during this season. Once in a while, tropical moisture will merge with highly modified continental or maritime polar air in China or the East China Sea to form a frontal boundary. This boundary will move over Kyushu and bring periods of rain and rain showers to the local area. As with the rainy season, the predominant form of severe weather that is experienced in summer is thunderstorm activity. While this activity is still more frequent than during the winter and fall seasons, it dramatically decreases from the frequent activity experienced during the rainy season. The reason for this is the presence of the subtropical ridge. This ridge will cap off and prevent any vertical development of any cells that would otherwise develop into thunderstorms. However, if the ridge shifts eastward enough to allow the moisture-laden flow of the southwest monsoon to move over the local mountains, thunderstorms can be expected. A forecaster must remain particularly vigilant during this season, as convective cells will frequently develop over the local area before any significant echoes are picked up by radar.

(2) Precipitation. The amount of precipitation received during the summer season drops dramatically from 12 inches per month during the rainy season to 8 inches per month in summer. All precipitation this time of year is liquid in form and predominately showery in nature. Infrequently, a weak polar front will move into the area, producing intermittent periods of light rain and rain showers. Frontal precipitation during this season is predominately light. Other sources of precipitation are showery in nature and usually heavier than frontal sources.

(3) Winds. The average wind direction and speed during the summer season is west to southwesterly at 8-10 kts. This is an increase from the 4-6 kts seen throughout the rainy season. The sea breeze is also prevalent during this season and it occurs more often as there is not as much rain or frontal activity. Like the rainy season, the winds can be expected to pick up to 8-12 kts with gusts near 20 kts during the day and

decrease to light and variable overnight. The diurnal affect on local winds here is very strong, especially during this season. Even when models forecast up to 10 kts of surface winds with up to 18 kt gusts potential, the winds tend to drop off to light and variable overnight. The summer winds will increase up to small craft force on average about once per week. Diurnal winds will often increase in intensity to frequent gusts near 20 kts. Gale and storm conditions are rare during the summer. Most of the high wind periods during summer are produced by the infrequent tropical cyclones that move into the area from south and east of Kyushu.

(4) Temperature and humidity. July and particularly August are the most uncomfortable months of the year as the daily temperatures and humidity levels peak. The full affect of this summer heat is usually felt by the first week in August. The average daily temperature is up 6-10° F from the rainy season's 70°F. By August, daily highs can be expected in the mid to upper 80°s F, and even up in the 90°s F on some occasions. These temperatures combined with an average daily humidity level in excess of 70% results in nearly constant red or black flag conditions. During a normal summer season, black flag conditions will only be reached for 2-4 hours per day during maximum heating. However, during an exceptionally dry rainy season (such as one that would occur during an El Nino year), black flag conditions will sometimes occur all day and even into the evening hours. The abundant rainfall of the rainy season tends to moderate the intense heat of the summer sun and lower the average daily temperatures. But with the absence of these rains, the sun's heat is allowed to permeate the local climate and result in a dramatic increase in daily temperatures.

d. Fall. The fall season is marked by a slow decrease in average temperatures and humidity levels, making it considerably more comfortable. The average daily temperature slowly falls to 64°F as the polar front again begins to appear over Kyushu. By October, infrequent and weak polar outbreaks begin to occur over the Yellow and East China Seas.

(1) Cloudiness and weather. With the onset of the fall season, the haze that is seen almost daily during the summer begins to fade away. By late fall, there is practically no haze remaining in the local area. The clearer atmospheric conditions along with decreased cloud cover are signs of the transitional fall season. As the subtropical ridge subsides and cooler air from the mountains of China begins to flow across the Yellow and East China Seas, the polar front begins to influence the local

area. During this season, there is very little severe weather to speak of. With the retreat of the subtropical ridge, the warm, moist air conducive for thunderstorm activity also disappears. In extreme circumstances, a moderate polar outbreak can produce thunderstorms as the cool air interacts with the warmer off-shore waters. Early in the season, tropical cyclones have been known to move into the area, bringing tropical moisture and instability into the area, producing local thunderstorms.

(2) Precipitation. The average monthly precipitation slowly drops from 8 and 1/2 inches early in the season to 3 and 1/2 inches by the end of the season. Most of the precipitation that falls is in liquid form. However, it is possible for snow late in the season. Most of the fronts that move through the area during this season are weak and have very little precipitation associated with them: usually 1/2 inch or less. Most of the precipitation falls as showers that form in the cold air behind fronts that are fueled by the weak polar outbreaks that begin the local transition from summer to winter.

(3) Winds. During the fall season the average winds slowly shift from west to northwest. The average wind speed throughout the season is 8 kts. Early in the season, the diurnal sea breeze can still be a factor. However, by the end of the season the sea breeze is no longer a local factor on local winds. As the subtropical high shifts southward, the predominant influence on the local wind regime are the dynamic high pressure masses associated with weak polar outbreaks that begin to appear by mid-season. The average number of wind advisories dramatically increases with the onset of this season. Small craft force winds occur approximately twice per week and gale force winds occur about once per month. Storm force winds are rare, but can occur when a strong gradient brings northwesterly winds on station, and funneling increases the winds intensity. Other directions can result in funneling on station, and forecasters should pay particular attention to the surrounding geography with respect to the gradient.

(4) Temperature and humidity. With the return of the subtropical ridge to the tropical waters southeast of Kyushu, the average daily humidity levels begin to rapidly decrease. Early in the season, daily temperature drop to an average of 73°F. By the end of the season, the average daily temperature is down to 54°F and daily lows can fall within the mid-40s.

e. Winter. Winter is marked by the predominance of northwest wind flow, low humidity and cooler temperatures. For Sasebo, winter begins in early December as the first thrust of polar air reaches the local area. The first snowfall usually occurs by the ninth day of December. The warm waters surrounding the island of Kyushu having a moderating affect on the local temperatures. However, falling snow very rarely accumulates in Sasebo, except at night. Temperatures will rarely dip below the freezing point, and if they do, it is only for short periods of time. By mid-March, the polar outbreaks become weaker as the season transitions to spring.

(1) Cloudiness and weather. As in fall, the winter season is dominated by good visibility and scattered to broken conditions. As the season progresses, stronger fronts begin to pass over the station. On average, a front will pass over the station every 4 to 7 days. Occasionally, a strong polar outbreak will occur lowering surface temperatures enough to allow falling snow to accumulate during the day. These extreme conditions rarely last for more than 24 to 36 hours. These conditions are serious for the local area as there is not an established snow removal plan for the area. If conditions are too hazardous, normal base operations will cease until the snow and ice melt. Thunderstorms occur in winter but are not near as frequent as in the summer. Winter thunderstorms are usually shallow and short-lived due to the nature of their convective structure. These thunderstorms lack the rich, warm moisture of summer-time counterparts. Wintertime thunderstorms form as a violent reaction when the cold polar air from China and Siberia mix with the warm, moist air over the Korean Straits. They can be violent with strong winds and heavy downpours of rain, ice pellets, or snow pellets. The comparison between the two types of thunderstorms would be like comparing the explosion of a small firecracker (summertime) to that of a cherry bomb (wintertime).

(2) Precipitation. This is the only season of the year that produces frozen precipitation of any significant quantity. In spite of this, most of the precipitation received during winter is still liquid in form. Rain is received from moderate to strong cold fronts, laden with moisture, as they pass over the station. By comparison, the average precipitation amount per frontal passage increases from less than 1/2 inch in fall to an average of 3/4 to an inch in winter. By mid-December, occasional snow flurries are a common occurrence in the cold air behind passing cold fronts. Due to the warm ocean waters that

surround Kyushu and lie in the local harbor, snowfall accumulating long-term on station is very rare.

(3) Winds. The predominant wind direction during the season is northwest and the wind speeds increase. The diurnal sea breeze is no longer present during this season. Often during polar outbreaks, the winds will actually increase above the expected gradient level indicated with forecasting models. This is due to an increased thermal gradient, resulting from cold air rushing off the Korean Peninsula, across the straits, and into the local area. Wind advisories, however, increase dramatically during this season. Small craft winds occur roughly once every 3 days with gale force winds once every other week. Storm force winds are rare, but as in the fall, a strong northwesterly gradient combined with a strong polar outbreak can bring storm force winds to the local area for up to 12 hours.

(4) Temperature and humidity. The average temperature during winter is 42°F. However, an average wind speed of 8 to 10 knots creates a wind chill temperature of 27°F. Even though local temperatures remain in the 40°s F and 50°s F throughout much of the season, the cold northwesterly wind flow keeps the wind chill temperatures near or below the freezing point. Due to the warm ocean waters that surround Kyushu and the local harbor, station temperatures rarely fall below freezing. When they do, it is usually for very short periods of time at night. In extreme cases, a strong polar outbreak can keep the temperature at or below freezing for 24 to 36 hours, especially if falling snow accumulates overnight.

CHAPTER 8
Forecasting

1. Forecast Tools

a. Upper air charts

(1) 200-300 mb: The jet-streams are lower in elevation in the winter and higher in summer. Therefore, the 300mb chart will catch most of the detail of jet-streaks in the winter, and the 200mb chart should be used in summer. In general, the Polar jet separates colder, Polar air from the milder mid-latitude air to the south. The subtropical jet separates the mid-latitude air from the tropical air. On rare occasions, there is a third jet-stream, called the arctic jet, which is north of the Polar jet, and separates extremely cold Arctic air from the Polar air. The Arctic jet can form only when extremely cold air develops in the far north during winter. However, there always is a Polar jet and a subtropical jet.

(2) 500 mb: PVA and NVA should be analyzed when a vortmax exists. As a rule-of-thumb, if PVA exists at 500 mb, there is probably upward vertical motion from the surface through 500 mb (actually to the tropopause level which is typically between 300 mb and 200 mb locally) caused by PVA alone. The best-case scenario for dynamic forcing for upward motion on the synoptic scale is for strong PVA at 500 mb to be accompanied by strong warm air advection from the lower level through at least 700 mb. Then there is both the thermal and vorticity advection providing lift. If cold air advection is occurring with PVA, then the air would tend to sink, and the resultant vertical motion caused by competing influences.

For Kyushu, except in the case of strong polar outbreaks, the 500 MB flow remains relatively zonal and flat. Long waves will pass through the area. However, Kyushu tends to be more at the base of the trough than in the center of it. This is due to the island's proximity to the tropics. In the summer, any vorticity levels above 12 are a good indication of impending thunderstorm activity. However, in the winter high vorticity levels and strong cold air advection are needed to trigger thunderstorms. Winter vorticity levels should be at least 16 before a winter time thunderstorm is even considered.

(3) 700 mb: The flow pattern on the 700mb chart is used as a steering mechanism for air mass or single cell thunderstorms, although large areas of organized convection, called mesoscale convective systems (MCS), are steered by the

thermal wind (thickness pattern). Even though the 700 mb flow can be used to predict the movement of single cell thunderstorms, a severe cell will sometimes split, with one cell usually moving to the right of the path of the original cell. This “right-mover” can be a tornadic thunderstorm. As a rule-of-thumb, a 700 mb temperature of 14^{o} C or higher is too warm to allow thunderstorms to develop. Such a high temperature happens in major heat waves and also by subsiding, or sinking, air diverging in a high-pressure system, with the air warming as it sinks.

(4) 850 mb: The sun does not heat the air. The sun’s radiation, mostly the UV wavelengths, heats the ground, and then the ground heats the air above it by emitting IR radiation in the form of heat. Analyzing for thermal advections is one of the major uses of the 850 mb chart. Typically, warm air advection (WAA) causes rising air and cold air advection (CAA) causes sinking air. If the dew point depression is 5^{o} C or less in the area of WAA, then lifting this warm (moist) air could result in clouds and subsequent precipitation. There can be other factors such as NVA or down-slope flow that would cause downward motion to counteract the upward motion caused by the WAA. Therefore, all the dynamic and mechanical factors causing vertical motions must be combined when attempting to forecast the resulting vertical motion field. WAA is probably the greatest dynamically-caused lifting mechanism over a synoptic scale. CAA, which often occurs in a winter outbreaks, would show up as 850 mb isotherms packed tightly together. The leading edge of the colder isotherms would be the Polar or Arctic cold front at 850 mb. When isotherms are packed tightly together and they are being advected into an area, that area will experience a rapid change in temperature. The stronger the winds that are associated with the advection, the faster the warm or cold air will move into the area. In an 850 mb baroclinic system, a well-developed short wave trough will show up on this level as a “closed low”. Over most of the Japananese Alps, the 850 mb level is below the ground level since 850 mb averages around 5,000 ft in our latitude. Computer model outputs are therefore extrapolated downward for what it would be if there were an 850 mb level at those mountain regions.

(5) Long wave vs Short wave. Long waves are hemispheric scale and barotropic. This means that the isotherms are parallel to the height contours (non-dynamic). No thermal advections occur except those moving with the wave. Short waves are synoptic scale and baroclinic, meaning thermal advections occur and are analyzed as isotherms crossing the height contours

at some angle (dynamic). If we cannot readily identify a short wave within a long wave, but see warm advection followed by cold advection in a part of the long wave, then a short wave is passing through the long wave pattern. Because they are smaller than long waves, the short waves move faster.

b. Surface Charts. To fully appreciate the scope of the atmosphere’s behavior, forecasters must analyze what the air is doing in the horizontal, in the vertical, and over a period of time. Model outputs at the surface and aloft give a picture of the atmosphere at a given time, and by looking at a series of different charts over time forecasters see the evolution of the weather.

(1) Japanese Charts. Japanese Meteorological Agency (JMA) charts are available for view at the JMA website. These charts are generally very reliable for the movement of local systems. They are also extremely useful in making a rain versus no rain decision. The surface prognostic charts depict millimeters of potential rainfall. While this product is not a good tool for forecasting rainfall amounts, it is an excellent indicator of the expected intensity of incoming precipitation. One area that JMA charts lack good detail in is wind speed. Wind barbs are shown on the surface prognostic charts, but are so sparsely scattered throughout the chart that the barbs are only useful in determining gradient force for a particular area.

c. Mesoscale Interactions. Mesoscale forecasting is very dependent on the structure and orientation of topographic features and local area effects that it produces.

(1) Surface pressure and winds. The JMV software is a tool for viewing and processing model forecast information. The viewer will give you wind direction to the nearest degree and speed to the nearest knot with just a point of the mouse. One of the weaknesses seen here with model prediction is the terrain. Models do not account for local terrain affects well. This always must be considered when issuing a wind forecast.

(2) Placement of pressure centers. Pressure centers are generally verified within 5 degrees. Local satellite images are an excellent tool that can be used to aid in this verification. When pressure centers are close enough to the local area, the local barometer can also be used as a verification tool. As with most models, the transition seasons tend to be the least reliable for placement of pressure centers.

2. Mesocale Interactions.

a. Regional surface observations. It is essential for forecasters to know the weather reporting stations around the local area

(1) Yokosuka. Figure 8-1 shows location of some of the reliable reporting stations that are particularly helpful in locating frontal systems in the immediate area of Yokosuka, especially during the spring Bai-u and fall Shurin. Tateyama, Oshima, and Miyake-Jima used together are representative of weather conditions in the approaches to Tokyo Bay and seaward to 50 NM from Yokosuka.

FIGURE 8-1. LOCATION OF RELIABLE REPORTING STATIONS

(a) Hachijo-Jima, station number 476780 (RJTH), is located 135 NM south of Yokosuka and is useful in locating the approximate position of migratory waves and the proximity of passing frontal systems south of the Kanto Plain.

(b) Miyake-Jima, station number 476770 (RJTQ), is located 70 NM south of Yokosuka and is helpful in locating migratory waves and frontal systems along the southern coast of Honshu.

(c) Oshima Island, station number 476750 (RJTO), is located 36 NM south of Yokosuka. This station is useful in forecasting strong southerly surface winds for Yokosuka. Northeast and southwest low level winds prevail at Oshima Island. Ahead of a cold front, winds at Oshima are moderate from the southwest and shift to the west after frontal passage. Frequently, westerly winds behind the cold front will back to the southwest giving the impression that the cold front still remains north or west of the station, but this is misleading. The occurrence of northeasterly winds at Oshima Island are a sign of bad weather during the winter, spring, and fall months, and indicate that the polar front is south of the station with a possible wave developing to the southwest.

(d) Tateyama, station 476720 (RJTE), is located on the southern tip of the Bozo Peninsula, 22 NM south-southeast of Yokosuka. Tateyama is well exposed to all southerly directions and aids forecasting strong surface winds.

(2) Sasebo.

(a) RJFU Nagasaki. This station is located on the southeast end of Omura Bay. Winds observed at this station are on average 4-6 kts greater than local area winds, but a good indicator of anticipated with approaching tropical cyclones and baroclinic low pressure systems that approach from the southwest.

(b) RJFF Fukuoka. Fukuoka International airport is located on the northwest shore of Kyushu. This reporting station is located approximately 5 NM inland from the Tsushima straits and is a great indicator for gusty northwest flow. The observed winds on average will be about 2-4 kts greater than local winds. A thunderstorm warning should be issued when thunderstorms are reported. Eighty percent of the time, thunderstorms will be on-station within 15 minutes after being reported.

b. Regional Wind Direction and Speed. Due to rugged topography, most reported surface wind directions are not representative when wind speeds are less than 10 kts. Strong understanding in local area funneling, land/sea interaction and heat islands will aid in accurately forecasting wind direction and speed.

c. Regional Temperatures. Temperatures and dew points can be misleading due to topographical effects and excessive heating. During the winter, successful and accurate frontal analysis over local area can best be achieved by careful analysis of the 850 mb level. At this level, the elements of winds, temperature and dew point are more representative of the overall synoptic conditions. Air mass discontinuities, therefore, are more easily seen. During the spring, summer and fall, continual analysis of surface plots will provide a general weather trend for good placement of synoptic elements. During the Bai-u/Shurin rainy seasons, a discontinuity of upper level synoptic features forms over Honshu due to strong influence by the mesoscale features. It has been observed that the mountain ridgelines block the northerly movement of the stationary boundary during spring, keeping the local area under cloudy skies and cool northerly wind, with periods of light rain. Cold air damming is also experienced during the Shurin as the ridgeline to the north and west of the Kanto plain blocks the movement of cold low-level air ridging over the area associated with strong high pressure over northern Honshu. A watchful eye on local area observations and attentive satellite analysis remain the best tools for tracking migratory waves and frontal boundaries.

d. Regional Pressure Tendencies. Surface pressure tendencies are representative and should be utilized to locate surface frontal systems; however, use only the three hourly tendencies exceeding 0.5 mb because they may be relied upon for defining trends due to the diurnal variations. The 1800Z diurnal pressure tendency in the Yokosuka area is slight, averaging -0.4 mb. Falling tendencies on the 0600Z observation are greater, averaging -0.8 mb. The diurnal rise peaks at 0000Z around 0.6 mb and again at 1200Z with 0.8 mb. With a high-pressure center over the Sea of Japan, and observations indicating rising pressure tendencies on the western side of the high, the high should be forecast to remain stationary, or to move very slowly and intensify. If the tendencies are rising to the east and falling to the west of the high center, the high should be forecast to move out at a moderate speed. The greater the tendency difference across the high, the more rapid the movement will be. This rule may be applied conversely to low-pressure systems. If pressure tendencies ahead of a storm show a fall of 2.0 mb in three hours, the average speed of movement of the storm will be about 25 kts.

e. Local Effects of Mesoscale Meteorological Elements. The ability to successfully forecast weather conditions over the local area rests on integration of mesoscale effects. Each weather element has at least one mesoscale feature that will affect wind, temperature, visibility, cloud cover, and frontal movement.

(1) Yokosuka.

(a) Wind Direction. Yokosuka is restricted in wind direction from the west. Yokosuka will either experience southwest or northwest winds. The same goes for a restriction of easterly winds. Yokosuka will either experience a northeast or southeast winds. There are no restrictions from the north or the south.

(b) Wind Speed. Wind speed presents more of a challenge in forecasting for Yokosuka than the surface wind direction. Significant factors that forecasters must take into consideration are topography, land-sea temperature distribution, and funneling possibilities.

(c) Temperatures. Due to the moderating effects of the nearby water of Yokosuka Bay and Tokyo-Wan, forecast temperatures for the Yokosuka area should be higher than the models indicate by 2-3°F in the winter months and lower by 3-4°F in the summer months. Moderate northeasterly winds will drop temperatures 5-7°F compared to mean climatic temperatures during the summer months due to advection of cooler temperatures from the eastern coast of Japan. During summer months, maximum daily temperature occurs earlier in the day (around 0300-0400Z), prior to the onset of a sea breeze.

(d) Pressure Tendencies. Yokosuka experiences a standard diurnal pressure tendency in a non-gradient type flow.

(2) Sasebo

(a) Wind Speed. Sasebo Bay is relatively well protected from most winds. Rugged mountains surround the harbor on all sides but the west. Funneling through some of the local mountain passes northwest and southwest of the station is quite common. When a northwest or southwest gradient of at least 10 knots is present on the surface, about 5 kts should be added to sustained winds and 6-10 kts to potential gusts. The bay is particularly vulnerable to high winds when they are from the southeast through the southwest. This is due to low topography and a large unobstructed wind field over the northeast portion of the ECS. In addition, a strong northerly or southerly gradient can produce high winds over Sasebo Bay, due to its north south orientation. A northerly gradient however, should be meticulously analyzed. A wind component as little as 345° can result in significant blocking, while the same gradient from direction 350 degrees would result in funneling. Small craft advisories are most common and occur frequently during both the summer and winter months. Gale and storm force winds only occur under strong synoptic situations. Most of the high wind regimes here are the direct result of either thunderstorm or typhoon activity.

f. Seasonal considerations

(1) Yokosuka

(a) Summer. The increase in pressure gradient across the Kanto plain will produce small craft force winds, and on occasion, gale force winds for several hours. The strength of the winds will depend upon the intensity of the low, at which latitude it crosses the Sea of Japan, and the strength of the subtropical ridge to the south of Yokosuka. The duration of these strong southwest flows will be dependent upon the speed and movement of the low. Normally, only ten thunderstorm days occur at Yokosuka each year, usually from late May through mid-October. During these warm months, air mass type thunderstorms will usually occur during the afternoon and early evening between 0600Z and 1300Z. Forecasters must clearly understand the dynamics of thunderstorms morphology and closely monitor the temperatures at 700 and 850 mb levels. If 700 mb temperatures are forecast warmer than 12° to 14° C, air mass thunderstorms cannot develop. If 850 mb temperatures are expected to become warmer than 15° to 17° C, no thunderstorms will develop. These high temperature ranges are caused by major heat waves and by strong subsidence in the eastern portion of a high-pressure system, with the air warming as it sinks. Thus, cumulus clouds cannot reach to the level of free convection. During the summer months, air mass thunderstorm activity occurs more frequently in the Kanto Plains valley and Yokohama area than at Yokosuka. Figure 6.4 is statistical data that depicts movement based on generating area. Data shows that it is rare for air mass thunderstorms to move toward Yokosuka, however for any thunderstorm developing to the northwest, movement indicates a fair chance of affecting areas just to the north of Yokosuka at Yokohama.

(b) Bai-u and Shurin. These seasons produce light and variable winds at Yokosuka, when the polar front is in the immediate vicinity of the coastline. With the polar front to the south of Yokosuka, the surface winds will have a northerly component. When the polar front lies to the north of Yokosuka, a southerly wind will prevail. It is important to note that during periods of strong southerly dynamic flow, wind speeds over the open waters of the approaches are significantly stronger than those winds experienced on base or the harbor area due to frictional effects. The spring and fall migration of the polar front marks the period of maximum precipitation and cloudiness over southern Japan. The first stages of the northward/southward migration of the polar front can best be observed by monitoring the Polar jet stream migration. The intensification of the Pacific High in the spring and the weakening of the Asiatic continental high will coincide. The reverse is true during the fall. Once the polar front has moved northward over the East China Sea during the Spring, a quasi-stationary high (1016 mb) develops to the north or northeast of Hokkaido, and the subtropical ridge extends westward from the Pacific High to the Philippine Islands. The high-pressure center to the northeast of Hokkaido ridges westward over the Sea of Japan. During the transition from winter to summer, cloudy skies are common, and weak cyclones move eastward along the polar front, now trapped between the two high-pressure centers. These cyclones do not ordinarily deepen, but rather appear as a series of weak, stable waves propagating along the polar front. Generally, rain will commence with the approach of a wave and cease when the center circulation passes to the east of the Kanto Plain. On occasion, the high pressure to the northeast will intensify and push the polar front south of Japan, resulting in partly cloudy skies over Yokosuka. If the high to the northeast weakens, the polar front moves north of Yokosuka. This oscillation will continue until the subtropical ridge becomes firmly established; higher surface pressure and upper-level height rises ensue, forcing the polar front to the north.

(c) Spring, Fall, and Winter. During these months, the prevailing wind direction at Yokosuka is northerly, with an average speed of 8-10 kts. The highest average occurs during the latter part of the winter months. Marginal small craft force winds are common during the winter months, especially during the daytime. Under these conditions, northerly surface winds will increase at sunset and remain at small craft force until late evening (1300-1400Z). Cold polar outbreaks push fast moving cold fronts across Japan throughout the winter months. These produce small craft or gale force winds, persisting for 12 to 18 hours. Sky cover in excess of 50% over the Kanto Plain is normal throughout the year, except in winter. During the winter months, when cold, dry continental air from Siberia passes over the Sea of Japan and the Sea of Okhotsk, it acquires considerable moisture and undergoes heating from the underlying warmer water. This results in an increase in instability, turbulence, and low-level moisture up to approximately 5,000 feet. With prevailing northwesterly winds at the surface and aloft, the flow of air is orographically lifted over the western slopes of the Japanese Alps, resulting in increased cloudiness and precipitation in that region. On the leeward side of the Alps, over the Kanto plain, fair skies result, and precipitation is rare. This condition occurs frequently during the months of November, December and January. During the winter, partly cloudy skies will be associated with an approaching cyclonic disturbance or upper-level trough. On occasion surface cold fronts during the winter months may pass through the Kanto Plain with no evidence of cloudiness. In those instances, frontal passage can be determined by an increase in wind velocity and a pressure rise. Following passage of a strong, fast moving cold front, temperature and dew point will show a rapid drop. A smaller drop in temperature and dew point accompanies the passage of a weak cold front. Maximum cloudiness occurs during the afternoon and consists of cumuliform type clouds. During spring and fall, minimum cloudiness occurs in the evening hours; during the summer, it occurs after midnight. During the summer, the eastern slopes of the Japanese Alps become the windward side and mechanical lifting of the prevailing southerly flow occurs. Under these conditions, warm, moist tropical air is orographically lifted, resulting in cloudiness and sometimes precipitation on the eastern slopes of the Alps.

(2) Sasebo

(a) The months with the highest frequency of low visibility are from mid to late-April through mid-June. During this time of the year, the convergence boundary “rainy season front” advects over the local area bringing warm tropical air over the cooler modified continental polar air resulting in rain, isolated rainshowers and low visibility due to thick fog.

The majority of thunderstorm activity at Sasebo occurs from spring through fall. The approach of a developing low pressure center or frontal system is not in and of itself an indicator of impending thunderstorm activity. Several months of detailed analysis has shown that there are specific indicators of impending thunderstorm activity in this area. The most common occurrence of thunderstorms is when a low pressure center is approaches from the Shanghai region and passes west of Sasebo. This brings warm, moist air into the local mountains where it is mechanically lifted, producing all the lift and instability necessary for thunderstorm activity. Southerly to southwesterly flow up to the 850 MB level is also a good premise for convective activity. This is especially true when this flow is associated with an approaching warm front with a pronounced developed moisture ridge.

(b) After a sufficient amount of cold air builds up in the mountains of Siberia and northern China, occasional polar outbreaks will occur over the Sea of Japan, Korean peninsula, and East China Sea which may produce snow over northern Kyushu and Sasebo. These polar outbreaks can be clearly seen on satellite imagery as the cold air over the warmer ocean water produces cloud lines of stratocumulus and cumulus. These lines reveal the near surface wind flow that is crucial to local snow forecasting. In order for this air to be cold enough to produce snow in Sasebo it must take the shortest path across the warmer waters of the Korean strait (north-northwest). This type of flow must exist in conjunction with a polar outbreak, 540 line over the southern coast of South Korea or over the Korean Strait, and a temperature of -7°C at the 750-mb level to forecast snow for the local area. If the flow aloft is equatorward of the surface flow, forecast snow showers. This will bring in overrunning warm air. This adds moisture to the equation, producing snow showers with large, wet snowflakes. The warmer the air aloft, the heavier the snow showers. This will persist for 12 to 24 hours. After 24 hours, strong high pressure tends to cap the vertical development of any cumulous clouds and limit shower activity. If a weakness develops in the ridge (known as a dirty ridge) while cold air is still flowing across the Korean strait, snow showers will begin to occur. The passage of a deep 500 MB trough (5400 meters or less) will often trigger a polar outbreak along with northeasterly flow from Russia and northern China across the Korean peninsula. Although a 500 MB height of 5400 meters or less is a good indication of a polar outbreak, it is not necessarily a requirement. The warmer air aloft, in this case, can actually act to enhance snow shower activity over the local area. The temperature in Sasebo rarely falls below the freezing point. This is a significant factor to consider in a snowfall accumulation forecast. In order for significant accumulation of snowfall, the ground must be frozen or at least near freezing. Significant accumulations will only occur at night or with extended shower activity. Extended shower activity will limit any diurnal heating produced by the sun, allowing falling snow to accumulate. However, at least 1 hour of steady snowfall is needed to cool the ground sufficiently to keep the snow from melting.

g. Land/Sea Breeze. The phrase "sea breeze" is used to describe the onshore wind in the daytime. Land-sea thermal contrast is sometimes accompanied by warm advection at onset of a sea breeze. In order to analyze the mesoscale structure, temperature distribution at onset of daytime onshore wind is analyzed hourly. More than ten percent of daytime onshore winds are of the warm-advection type. They tend to occur under relatively weak sunshine in cloudy weather or just after sunrise, with synoptic pressure increasing seaward. Although a land-sea breeze effect may occur at Yokosuka anytime during the year, it is predominantly a summertime phenomenon and can occur during breaks in the Spring Bai-u and fall Shurin rainy seasons. During the summer months, a lee-side trough over the Kanto Plain forms a Kanto Low with Tokyo and Yokohama acting as a heat island. Maximum heating for the day with an 8°F temperature spread between Yokosuka and open waters offshore is necessary to initiate a sea breeze. Winds aloft at 1,000 feet need to be light (less than 15 kts). The sea breeze normally commences between 0100Z and 0400Z under clear to partly cloudy skies with either a southerly or light northerly wind. The onset will depend on the wind and the amount of sky cover. If the wind is light from the north and fair skies prevail, the surface wind will become south to southwest 8 to 12 kts with gusts to 16 kts by early afternoon. If the wind is southerly, the onset of the sea breeze will increase the existing wind speed by 5-10 kts, with gusts during the afternoon hours ranging from 25-35 kts. A secondary effect of the sea breeze is cooling of temperatures with maximum daily temperatures occurring just prior to onset, normally between 0300-0400Z. Under these stated conditions, the sea breeze will occur 90% of the time and will normally end after sunset (especially during the summer). If the prevailing wind prior to onset of the sea breeze was light northerly, the wind will shift back to the north during the evening with speeds of 3 to 5 knots. If the prevailing winds prior to the sea breeze effect were southerly, the winds will decrease and remain southerly. When daytime heating ceases and radiation cooling begins after sunset, Yokosuka will be affected by a northerly land breeze of 5-10 kts. However, this is on occasion preceded by an initial northerly surge of near small craft intensity, which normally lasts for about one hour. With light northerly winds (5-10 kts) in the winter, the land breeze will reinforce it, producing marginal small craft force winds until the late evening. If marginal small craft winds are occurring throughout the morning and afternoon hours, the land breeze will produce small craft force winds commencing near sunset and persisting until near midnight. This situation occurs quite frequently during the winter months, especially for two or three days after a strong polar outbreak.

h. Kanto Low. Normally, the Kanto Low is a summer feature when an insolation-induced heat lows, cyclonic circulation is strengthened by the local strong sea breeze. The concave shape of the Kanto Plain also aids cyclonic circulation. Table 1 outlines the effects of the Kanto Low. The Kanto Low can also be produced by northwesterly flow over the Japanese Alps as discussed earlier. Sufficient daytime heating is required in order to obtain a closed circulation. However, clear to partly cloudy skies during winter/spring can enable the Kanto Plain to become enough of a "heat island" to generate a heat low. A very important fact that must be considered is that the gradient to the south of the Kanto Low can become strong enough to produce strong small-craft intensity (23-30 kts with gusts to 45 kts) southerly winds over Yokosuka/Yokohama areas. Winds can generate rapidly and will extend from the southern end of the forecast area (vicinity of Oshima) north through Uraga Suido traffic channel and along the western portion of Tokyo Bay. This may last anywhere from 15 minutes to 3 to 4 hours and is found with a strong mesoscale pressure gradient that is related to the location and intensity of the low. Similar to location of the Lee Trough, the exact center of the Kanto low and its intensity also cannot be forecast accurately and is determined to a great extent by the strength of the southerly flow over our forecast area.

Conditions expected w/o Kanto Low	**Local Effect by Kanto Low**
Wind: NE flow as high pressure extends across northern Japan	NE flow gradually veering to SE by early afternoon then S to SW from early to mid afternoon.
Clouds: Mostly cloudy to cloudy skies.	Onset of S wind pushes clouds into northern Kanto Plain. Local area partly cloudy mid afternoon until early evening.
Temps: Minimal heating forecast with cool NE flow and overcast skies	Rapid temperature increase with onset of S wind and partly cloudy skies.

TABLE 1. EFFECTS OF THE KANTO LOW

(1) Kanto Low Super gradient Wind System. On infrequent occasions, the combination of various weather parameters produces strong southerly winds that affect the approaches and

Tokyo Wan. In a general sense those parameters are a strong high pressure in the southern Sea of Japan and a well established lee low over the Kanto Plain, see figure 8-2. The sequence of events, which leads to these 25-35 kts sustained southwesterly winds are as follows:

(a) The southern portion of the cyclonic flow of the Kanto lee low will extend over Tokyo Wan and approaches.

(b) The valley between the Chogoku Mountains in western Honshu and the Japananese Central Alps, immediately west of the Kanto Plain provides drainage for high pressure from the Sea of Japan to the southern coast of Honshu at Ise-Wan.

(c) Upon reaching the southern coast, these winds moved eastward along the southern coast of Honshu, within a weak lee side trough.

(d) Upon entering the vicinity of the approaches to Tokyo Wan, this ribbon of super gradient winds are absorbed into the southern sector of the Kanto low circulation and generate northeastward into Tokyo Bay.

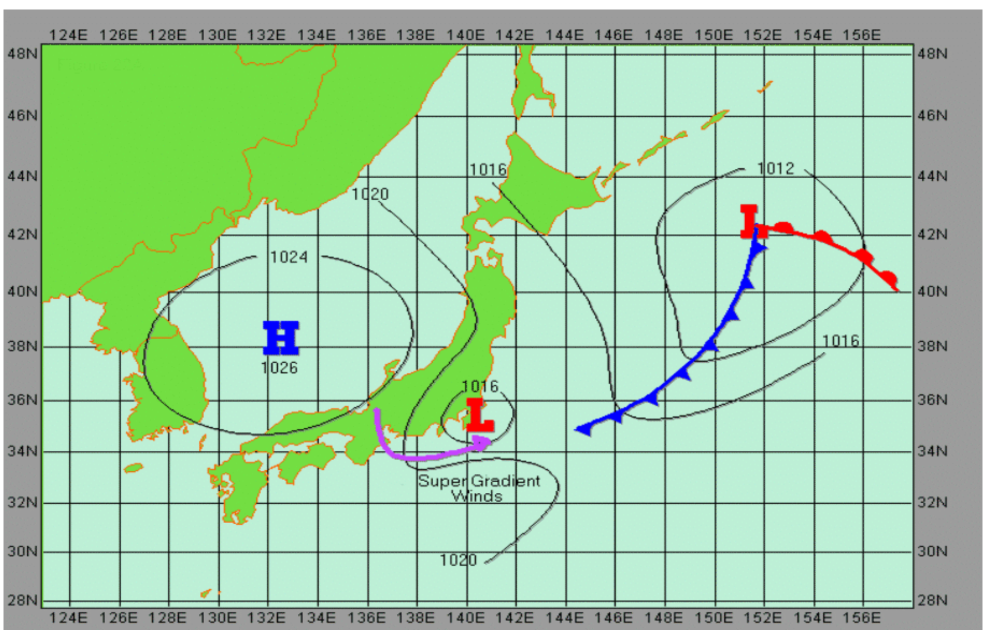

FIGURE 8-2. SUPER-GRADIENT SURFACE WINDS SCENARIO

(2) Kanto Low and Lee Trough. The Kanto Low and Lee Trough (known locally as the “Oshima Trough”) are the most significant topographically influenced mesoscale features that

present a major challenge for the Yokosuka forecast area. The Lee Trough is a dynamically induced trough formed by northwesterly flow against the Japanese Alps. This condition normally occurs with the passage of a NE-SW oriented cold front or the passage of a deep low along the southern coast of Honshu during the winter and spring. An inverted Oshima Trough can also be produced by the passage of a high-pressure center over northern or central Honshu. The actual movement of the trough can best be monitored by hourly observations within the Kanto plain. The Table 2 lists the effects of a Lee Trough.

	WITHOUT A LEE TROUGH	**WITH A LEE TROUGH**
WIND:	NW FLOW BEHIND COLD FRONT OR/500MB TROUGH PASSAGE.	NORTH TO NORTHEAST WINDS, OCCASIONALLY LIGHT AND VARIABLE, BACKING TO STRONG NORTHERLY WITH THE ONSET OF A LAND BREEZE
SKY:	RAPID CLEARING BEHIND COLD FRONT/500 MB TROUGH PASSAGE	CONTINUED CLOUDY SKIES BECOMING PARTLY CLOUDY AT NIGHT AS TROUGH FILLS AND LAND BREEZE BEGINS NORTHERLY FLOW
TEMP:	GRADUAL TEMPERATURE DROP BEHIND COLD FRONT	RANGES FROM LITTLE CHANGE TO A TEMPERATURE INCREASE ANYWHERE FROM 5 TO 15 DEGREES F, FOLLOWED BY A RAPID DROP WITH ONSET OF STRONG NE WINDS ASSOCIATED WITH ADVANCING HIGH AND FRESH POLAR OUTBREAK

TABLE 2. EFFECTS OF THE LEE-SIDE TROUGH

(2) A type of thunderstorm associated with the formation of a Kanto Low. Thunderstorms are steered and strengthened by the low. They generally develop to the north and northwest of Yokosuka and move east to southeast across the local area. The Yokosuka radar is capable of detecting this activity. Thus, advance warning can be obtained by closely watching radar reports and weather observations at stations to the west and north of Yokosuka. With Yokosuka in the warm sector, warm, moist air advected into the local area receives sufficient lifting from the cold front to trigger heavy rain showers and thunderstorms. Normally, however, cold fronts approaching from the north do not produce shower activity in the local area because the air preceding the front warms and dries

adiabatically as it descends the eastern slope of the Japanese Alps. Also, when the primary low is in the Sea of Japan, there is usually weak pre-frontal lifting associated with the southern portion of the front. Secondly, as warm frontal boundaries pass to the south of the Kanto Plain, the presence of a low-level jet at the 850 mb level is sufficient to produce embedded rain showers and thunderstorms.

i. Southeast Coastal Honshu Gale Ribbon. This effect occurs as a deepening low center, moving eastward along the Polar Front to the south of Honshu, moves northeast of Chiba and continues deepening while strong high pressure builds into the southern half of the Sea of Japan, see figure 8-3. Enhanced by topographic effects, air flows from the Sea of Japan to the southern coast of Honshu at Ise Wan. However, the pressure gradient effect is enhanced in this situation by the coupling of the lee trough with the tight pressure gradient around the dynamic low. This produces a ribbon, approximately 50-70 NM wide within which gale force (30-40 kts sustained, gusts to 50 kts) winds are found. Winds in Tokyo Wan may be northeast at 10-15 kts, backing to northwest 10-15 kts between Oshima Island and the Raga Suido Traffic Channel, further backing to gale west-southwest in the open waters south of the Izu peninsula. This feature will continue until the low moves far enough eastward, allowing high pressure to ridge into southeast Honshu.

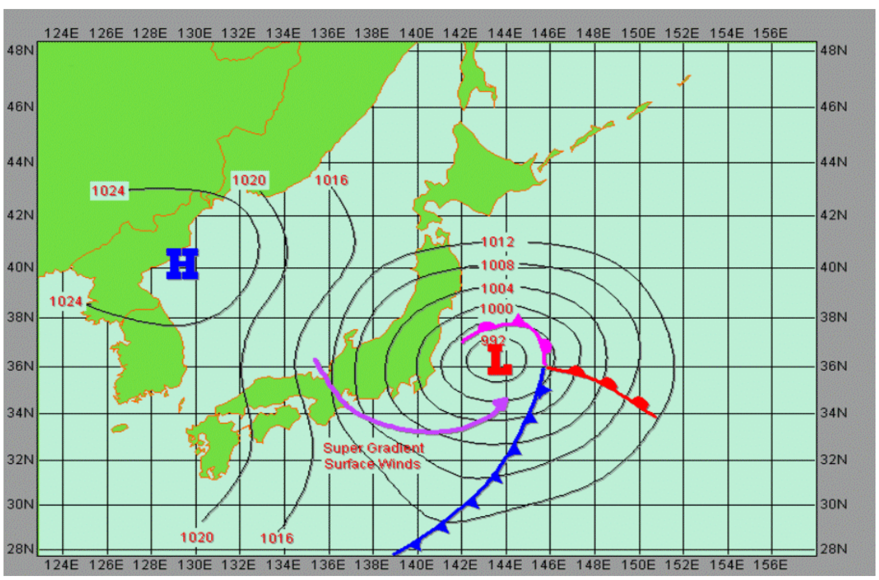

FIGURE 8-3. HONSHU COASTAL GALE RIBBON

j. Smoke/Haze. Smoke and haze can reduce the visibility at Yokosuka, due to the heavy industrial cities located throughout the southern Kanto plain region. This is especially pronounced with a subsidence inversion aloft and light northerly winds (winter). With the onset of a sea breeze, an actual wall of smoke and haze may be observed moving northward across Tokyo Bay, preceding the sea breeze front. Thick smoke and haze may persist for several days when a stagnant high covers the local area. With light and variable winds, visibilities will range from 2 to 3 NM during the early morning hours, improving to 4 to 5 miles during the afternoon and to 7 NM from early evening to sunrise the next day.

k. Dust/Sand. The source of dust and sand, other than locally raised dust and sand, is the Great Basin of China. During the winter months copious amounts of airborne sand is available throughout the Gobi desert region because it is nearly vegetation-free and has minimal yearly precipitation amounts. During the latter part of the winter (March), sand may be carried aloft over this region and brought eastward by strong westerly winds aloft. It is deposited throughout South Korea and southern Japan. Pilots have reported observing sand at altitudes above 20,000 feet. Strong mid-latitude dynamic pressure systems centered over northern China and/or North Korea carry the sand as far eastward as the Kanto Plain and beyond, occasionally reaching the west coast of North America, as turbulent mixing carries sand to great altitudes and the strong west to northwest winds aloft bring the sand eastward over Japan. As the winds aloft and turbulence decrease downstream, the sand falls to the surface. Under normal circumstances, the sand can restrict visibility for 8 to 16 hours. Surface reports from upstream stations will provide information about the advancing sand in sufficient time to forecast its occurrence.

l. Cold Fronts. Table 3 gives the mean number of cold fronts that pass within vicinity of Yokosuka. These include both cold polar outbreaks from the Asian mainland, as well as those cold fronts associated with cyclones developing along the polar front, which generate and pass to the immediate south and east of Yokosuka. Cold fronts that move over Japan from the Asian continent during the winter months are associated with low-pressure centers located well to the north of the local area. Normally, these centers develop over Manchuria or eastern Siberia. These systems move eastward over the Pacific and are absorbed into the semi-permanent Aleutian low-pressure system. Associated with these cold fronts are various amounts of middle and high clouds with relatively dry air in the lower levels. Cold frontal passage seems to occur most often during the early morning or early afternoon hours. This results in increased surface winds the night following frontal passage. It is not uncommon for the temperature to increase following a cold frontal passage. This anomaly is a result of post-frontal clearing due to lee-side effects and light winds. A migratory high, which follows the frontal trough across the Sea of Japan, is slow to affect the Kanto Plain because of "damming" by the Japanese Alps. This "lee effect", in conjunction with heating, creates lower pressure over the Kanto Plain and results in southwesterly wind flow. This wind flow is reversed when the migratory high finally advances to the east of Honshu, and the ridging "spills" south along the east coast into the local area, bringing with it a fresh surge of maritime polar air and small-craft intensity northeast winds. Temperatures will then undergo a marked drop. Generally, this sequence of events, from frontal passage to the onset of northeast winds, takes place within 6 to 12 hours and is strongest with an early morning frontal passage.

JAN	10.5	FEB	7.0	MAR	7.7
APR	6.7	MAY	9.0	JUN	5.0
JUL	1.5	AUG	1.5	SEP	5.0
OCT	5.0	NOV	11.0	DEC	9.0

TABLE 3. MEAN NUMBER OF COLD FRONTAL PASSAGES

m. Warm Fronts. Many lives are lost each year due to flooding and landslides associated with heavy warm frontal rains on the Japanese Islands. The low ceilings and poor visibilities affect aviation and boating activities as well. Warm fronts that will affect the Yokosuka area occur primarily during the fall, winter, and spring months. These warm fronts are associated with cyclones that develop over the East China Sea or Yellow Sea, and move eastward along the southern coast of Kyushu and Honshu. The passage of a cyclone and associated warm front causes widespread rain throughout southern Japan. A cyclone that forms in the East China Sea can cause heavy rainfall in the Yokosuka area within 18 to 24 hours. Cyclones that develop in the vicinity of Taiwan and move northeastward are far enough south to avoid western Japan, thus giving less indication of the onset of rain in the Yokosuka area. This occurs when the warm front does not move north of 30^{o} N until moving east of 135^{o} East. Warm frontal precipitation will end once the low center moves east of 140^{o} East.

n. Predicting Snow and Rain in Yokosuka. The difference between a forecast of snow versus rain can be of considerable operational significance. Refer to Appendix E (Rain vs. Snow Worksheet) to work up the specific parameters. One inch of rain poses no serious threat to local base operations; however, the same amount of precipitation in the form of snow may equal 10 inches of snow. Locally, hazardous snow conditions are defined as an accumulation of 2 inches or more (i.e., the equivalent of 0.2 inches of rain). It is for this reason that potential systems must be closely monitored and evaluated. Although Yokosuka is rarely buried under a blanket of immobilizing white snow, it has occurred at times under the proper conditions. Aloft, southwesterly winds at both the 700 mb and 500 mb levels must be present with their associated troughs in the Sea of Japan. The combination of cold northerly flow at the surface and low levels with warm, southerly flow aloft produces significant overrunning. There are two synoptic situations that can result in snowfall in the Yokosuka area.

(1) Synoptic Situation 1. The first is with the development of a lee trough to the south of the local area about 12 to 24 hours after frontal passage, see figure 8-5, and the position of the high northeast of Yokosuka providing advection of mP air to Yokosuka. When the trough drifts northward, generally during the early morning hours and/or in the evening, cloudiness and isolated precipitation in the form of showers may be present and a trace of snow will occur. Note that when a north-south oriented frontal system passes across Honshu, the northern Kanto Plain (RJTT, RJTY, RJAT, and RJTA) will experience more cloudiness and showers with passage of the front. Yokosuka will generally remain dry until the development of the lee trough.

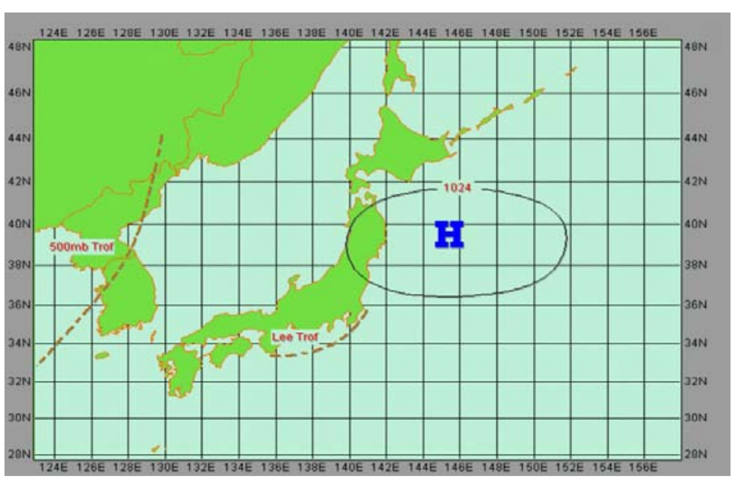

FIGURE 8-4. PLACEMENT OF THE LEE-SIDE TROUGH

(2) Synoptic Situation 2. The second situation that can result in snowfall in the Yokosuka area is when the polar front

is located south of Japan and a low-pressure center forms along the front and tracks northeastward, south of the local area, see figure 8-5. In this situation, a cold ridge (not a cut-off high) of the Siberian High must also be present, extending across northern Honshu into the Pacific Ocean east of Tokyo. This cold ridge produces a "damming effect" over the Kanto Plain, which often times can extend far enough southward to encompass Yokosuka. During this damming effect, the cold high protrudes southward as a nose or finger of high pressure with associated cold temperatures in the lower levels (the surface through approximately 850 mb). This damming effect is also a result of the Japanese Alps north and west of Yoksuka and is enhanced by the cold Oyashio Current, which flows southward along the east coast of Honshu. Both features result in a funneling of cold air southward.

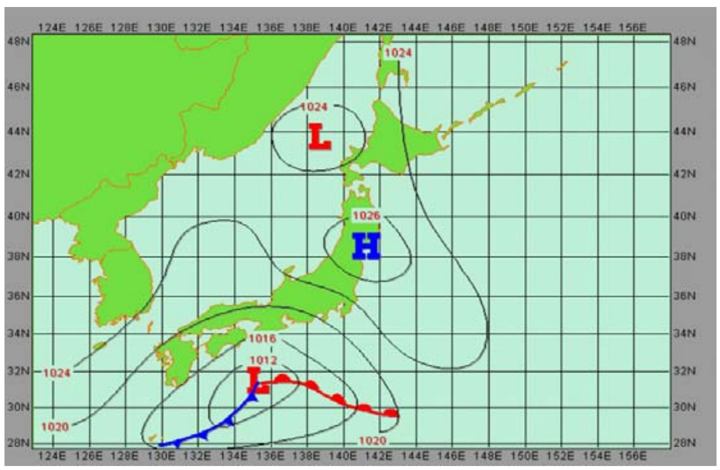

FIGURE 8-5. LOW AND COLD RIDGE COMBINATION FOR A SNOW EVENT

(3) Location of the High. The location of the high determines the amount of overrunning, and therefore, the amount of precipitation that occurs. If the high is located east and south, refer to figure 8-5, warm, moist air is provided aloft and a moderate amount of snow (i.e., 2 to 3 inches) usually occurs. If the high is centered south of 30° North, figure 8-6, the return flow from the high is warmer than that from a high located further north, and due to warmer return flow holding more moisture, heavier amounts of precipitation will occur at Yokosuka. The high near 37.5° North-141° East results in a cold wedge of air at the lower levels, reducing the moisture content. In this instance, accumulation is usually around 2 inches or less.

(a) Significant Precipitation. Figure 8-6 represents a very rare event that produced significant snow for Yokosuka. The high centered near 27° N-150° E pumped copious warm mT air northward which overran the cold mP at the surface. The precipitation over Yokosuka was in the form of snow and the accumulation from this particular system totaled 12 inches.

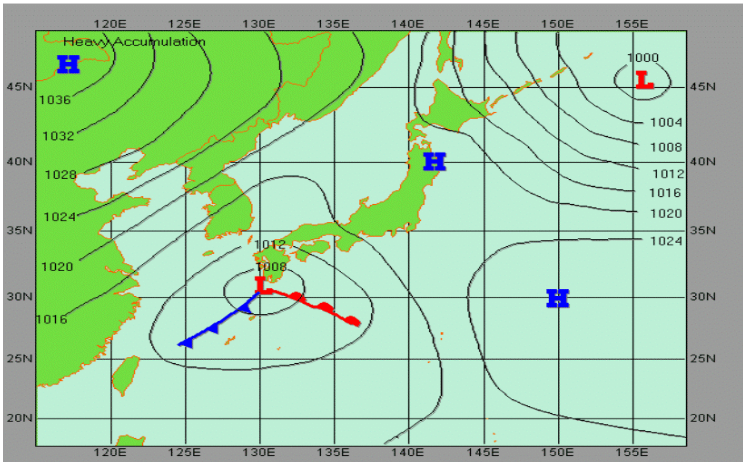

FIGURE 8-6. SYNOPTIC PICTURE FOR A SIGNIFICANT SNOW EVENT IN YOKOSUKA

(b) Trace Precipitation. In figure 8-7, the lack of return flow of warm and moist air aloft from the sub-tropical high resulted in only a trace of precipitation. A cold wedge (damming effect) at the surface was not present due to the lack of a cold high immediately north (near 37° North).

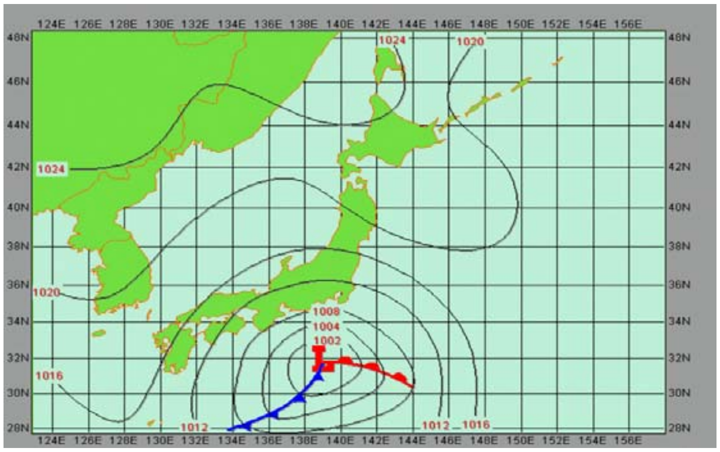

FIGURE 8-7. SYNOPTIC PICTURE FOR TRACE AMMOUNTS OF FROZEN PRECIPITATION

(4) Thermal Considerations. The type of precipitation

that reaches the ground (rain or snow), particularly in borderline situations, is dependent on two factors: (1) whether there is a layer of above freezing temperatures between the ground and the level at which the precipitation is forming, and (2) whether this layer is sufficiently deep to melt the falling snow. The vertical temperature distribution, layer thickness, and the freezing level must be determined.

(a) Lower Levels. The forecaster needs to consider what type of "thermal change" is taking place or is expected to take place, particularly at the lower levels. In most cases where precipitation is occurring, warm air advection and upward vertical motion are also occurring due to low surface pressure. This warming acts to change the precipitation to rain, even if it starts out as snow. If***, and this is a key factor in Yokosuka,*** there is cold air advection or even weak warm air advection in the lower levels, this process of changing snow to rain is upset. The process is disrupted because maintaining of the subfreezing air in the layers near the surface retards the effect of warming. Cloudy skies in the winter are capable to hold back warming of air.

(b) Warm Layer Depth. The depth of the layer Required for snow to melt varies from 750 to 1,500 feet, depending on the snowfall type, melted drop size, and lapse rate. Generally, if the freezing level is at or above 1,200 feet all the snow will melt.

(c) Cold-core Low. In addition to local effects, if the precipitation is associated with a cold upper low (cold-core low), there is little, if any, warm air advection. In borderline situations precipitation may persist as snow, or will tend to turn to snow, if it started as rain. This is a result of cooling due to upward vertical motion (adiabatic cooling) with a cold-core low.

(d) Evaporational cooling. Evaporational cooling takes place as precipitation falls though unsaturated air between clouds and the surface. It can be very pronounced if the lower layers are dry and precipitation has just started. If temperatures are above freezing in a layer deeper than 1,200 feet, in the lower layer the precipitation may still fall as snow, since evaporation of the snow lowers the temperature in the lower layer until freezing is reached/approached. Actual cooling can be as much as 5-10°F within 1-2 hours. After saturation is reached in these lower layers, evaporational cooling stops and the effect of any warm air advection is reinstated. However, this does not mean it is going to instantaneously change to rain. Firstly, the temperature may have dropped several degrees below freezing and considerable snow may have fallen. The melting of snow to rain (liquid form) during its descent also acts to cool the layers to a small degree. In other words, the reheating due to warm air advection may be too late to bring a change to rain.

(5) Synoptic, Regional, and Local Paramter Summary. The following parameters must be considered in forecasting snow versus rain. The location of the snow-rain zone depends upon a relatively small-scale synoptic considerations and local effects.

(a) Lee-side Trough. When a lee-side trough is forecast to be present and the 700 mb trough is east of Yokosuka, providing that forecasted upper-level temperatures indicate cold air aloft, forecast snow.

(b) Surface Low south of Japan. When a low pressure center is expected to track south of Japan the following parameters should be considered when determining a rain vs. snow event.

1. The forecasted track of the low and whether this position favors precipitation.

2. The forecasted low level wind flow (surface to 2,000 feet.)

3. The forecasted position of a cold ridge northeast of the surface low.

4. High/ridge south of 38°N, forecast snow and High/ridge north of 38°N, forecast rain.

Based on observations at Yokosuka, the critical surface temperature for snow is 38°F (3.3°C) for snow showers with a leeside trough, and 33.8° F (1°C) for snow associated with a low pressure center south of Japan. The critical temperature for mixed precipitation is 38.5° F (above 38.5°F equals rain) (3.6°C). These temperatures are the critical temperature values *after* precipitation has begun, and already account for the cooling that can be expected as a result of evaporational cooling. Surface temperature by itself is not an effective forecast criterion. Temperature advection aloft is also a critical consideration. The critical temperature at the 850 mb level is -7° C for snow and -3° C for mixed rain and snow. The critical temperature at the 700 mb level is -11° C where a surface low-pressure center is south of Japan. With a low-level surface inversion and very cold air near the ground, snow may fall even with the 700 mb temperature as high as 0° C. Since the temperature inversion is usually located near the 850 mb level and well below 700 mb, the temperature at one level may not be indicative of any relatively deep layer of the atmosphere. This can be overcome by using thickness values of the layer. A major aid in this situation is the wind and temperature reports from the top of Mt. Fuji. These reports provide the forecaster with an hourly update of temperature advection and relative position of the 700 mb trough.

(6) Thickness values. The following critical thickness values should be considered together, rather than individually, when evaluating the snow versus rain problem. (The 12 and 24 hours forecasts of these thickness values are of major importance in the snow versus rain problem). The height of the freezing level is extremely difficult to predict, but is one of the most critical thermal parameters. The critical value is 1,200 feet.

Layer	Low south of Japan	Leeside trough
1,000-850 mb	-Rain 2,829 meters or more -Mixed 2,828-2,795 meters -Snow 2,796 meters or less	-Rain 1,303 meters or more -Mixed 1,295-1,303 meters -Snow 1,294 meters or less
1,000-700 mb	-Rain 5,381 meters or more -Mixed 5,380-5,326 meters -Snow 5,325 meters or less	-Rain 2,798 meters or more -Mixed 2,797-2,785 meters -Snow 2,794 meters or less
1,000-500 mb	-Rain 1,522 meters or more -Mixed 1,521-1,500 meters -Snow 1,499 meters or less	-Rain 5,287 meters or more -Mixed 5,286-5,261 meters -Snow 5,260 meters or less

TABLE 4. THICKNESS AND DETERMINING RAIN VS. SNOW

(7) Wind direction. For snow, the surface wind direction should be northwest through east-northeast. Boundary layer winds (1,000 and 2,000 feet) must also be from these directions (i.e., 070 degrees or more, northerly). This is an indication of the strength and vertical extent of the ridge to the north of Yokosuka (i.e., it gives an indication of the

height of the cold layer at the surface with the synoptic situation of a low to the south of Japan). Aloft, the 700 and 500 mb winds are southwesterly and thus provide overrunning. As the low-pressure system moves east or east-northeastward along the southern coast, it generally deepens, aided in part by its movement over the warm Kuroshio Current. With deepening, the tightening pressure gradient will increase the northerly wind speeds over our forecast area and increase the volume of low-level cold air advection. After exiting Tokyo Bay, this dome of cold air spreads across the outer approaches and becomes shallower. It is not uncommon to see this reflected by the rain/snow line oscillating in a narrow east-west oriented band between Tateyama (47688) and Oshima Island (47675).

(8) Ceiling Height. The height of the ceiling at the onset of precipitation is a key to the humidity of the lower layers, and is therefore a clue to the amount of evaporational cooling that will take place to retard any change from snow to rain. The higher the ceiling, the more cooling will take place.

(9) Local Effects. The close proximity of the bay can limit evaporational cooling and may raise the freezing level slightly, or hinder the lowering of the freezing level in borderline cases. Local hills surrounding Yokosuka can also increase the likelihood of snow. The cold Oyashio Current, located off the east coast of Northern Honshu, can enhance the low level ridging (damming effect) that takes place, when a low and associated frontal system are located to the south of the Japanese islands.

(10) Notes. While thickness values near 1,290 m indicate mixed precipitation, it should not be assumed that there will not be measurable amounts of snowfall. Generally speaking, the snow will have a high water content (wet snow), but all the snow will not necessarily melt as it falls. Therefore, this can result in small accumulations usually about one inch or less. As with the thickness values, which indicate a forecast of mixed rain and snow, colder temperatures (near 33.8°F) may result in appreciable amounts of snowfall. However, accumulation is generally negligible since much of the snow melts on contact with the ground. In the case of showers associated with a leeside trough, if the surface temperatures are in excess of 37°F and snow showers may still occur. Use the same critical temperature listed on the worksheet (Step 4.B) if the 700 mb trough is east of Japan. In that case, look for snow showers. In order to forecast the 850 mb temperature: forecast the movement of the 0° C isotherm at the 850 mb level during the

forecast period, select points on the 0°C isotherm that lie between the thermal ridge and the trough as follows: one or two in the apparent warm advection area and one or two in the apparent cold advection area. Apply the following rules:

(a) Warm advection area. If the point lies in a near saturated or precipitation area, it will remain nearly stationary with respect to the contour trough. If the point lies in a non-saturated area but is expected to become saturated (or to actually lie in a precipitation area), then it will fall in these two categories, it will advect with about 50% of the wind component normal to the isotherm.

(b) Cold advection area. Advect the point with approximately 75-80% of the wind component normal to it.

(c) In the case of a closed, slow moving low at the 850 mb level, the 0°C isotherm will move eastward with respect to the closed low as the cold air is advected all the way around the low.

(d) For forecasting the dew point and movement of the isodrosotherms, first advect the isodrosotherms at 100% of the wind component normal to the isodrosotherms until the 850 mb level is saturated. Then, advect the isodrosotherms at the same advection speed as the isotherms.

APPENDIX A
Thumbrules

1. Yokosuka

a. When you have prevailing southwest to west winds, the heliport ASOS observes wind speeds 5 to 10 knots less than NOAC Yokosuka.

b. Japanese reporting stations use the plain language remarks "Yellow Sand"). In Yokosuka raised sand and dust events have a shorter duration and occur only 2 or 3 days a year. Strong northerly winds (20 to 30 kts sustained, gusting to 50 kts) occur after a strong polar outbreak and result in blowing sand or dust at Yokosuka. The sand or dust comes from the northern Kanto Plain and can be observed at Iruma, station 476430 (RJTJ), about one hour prior to its arrival at Yokosuka

c. Do not use 850 mb over the Japananese Alps but employ the 700 mb for the same use. For the Sasebo area with 70% or greater relative humidity represents broken to overcast conditions. Areas with 80% or greater relative humidity indicate the possibility of rain or rain showers. For accurate determination of these parameters, check the humidity at the 700 MB level and the local synoptic situation.

d. Siberian High formation occurs about every 5 to 7 days and with the easterly migration pattern, when it reaches Japan, the Kanto plain experiences an average of four days of warm temperature followed by three days cold winter weather. During mid-winter, cP air mass can expand as far south as the northern Philippines.

e. A cyclone that forms in the East China Sea can cause heavy rainfall in the Yokosuka area within 18 to 24 hours

2. Sasebo

a. The 700 MB level will be the most important level during the development of the local area forecast. Any area with 70% or greater relative humidity could indicate the presence of either frequent rain showers or steady rain. This would depend on the synoptic situation. Areas of 80% or greater relative humidity at 850 MB that overlap the 70% or greater values at 700 MB indicate possible areas of rain or rain showers. If less than 80% relative humidity is present at 850 MB, this could indicate an approaching frontal system. Anticipate the onset of precipitation as the 80% isopleth crosses the station at 850 MB.

APPENDIX B
Tropical Cyclone Tracks

1. Western Pacific. Tropical cyclones can occur year-round in the western Pacific Ocean (WESTPAC) with an average of 31 Tropical Storms occurring per year. This is strongly correlated with the western Pacific Ocean having the largest source of warm water on the globe, refer to figure 9-1. The "typhoon season" or period of greatest activity runs 01 June through 30 November, with a peak occurring in August and September for the region south of Japan. In general, formation areas are related to the orientation of the monsoon trough in the Philippine Sea and South China Sea between 5 and 15° North. Due to cooler waters, and the fact that the monsoon trough is located south of the equator during January through March, minimal tropical cyclone activity is experienced during this period. El Nino events shift formation of tropical cyclones east towards the International Dateline and La Nina events tend to increase tropical cyclones with cyclones taking a more westerly track over the Philippines and towards Vietnam.

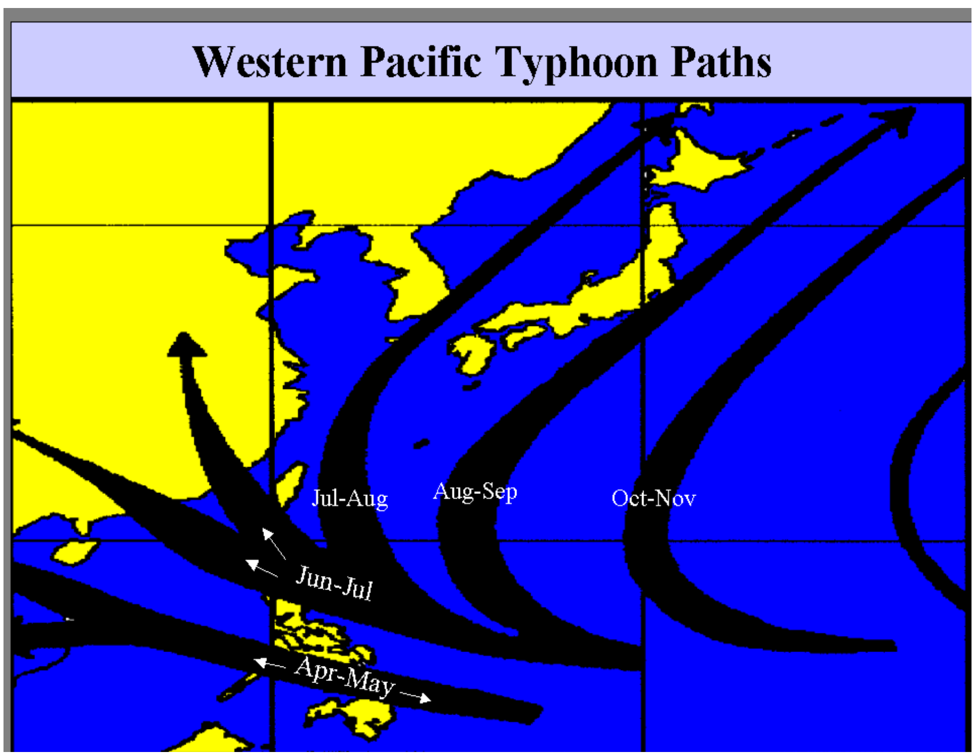

FIGURE 9-1. WESTERN PACIFIC MEAN CLIMATOLOGY FOR THE WHOLE YEAR

2. Climatology Mean Paths of Tropical Cyclones for the western Pacific. The following figures are taken from the Typhoon Havens Handbook of the Western Pacific.

MEAN PATHS FOR DEC 24 - JAN 8

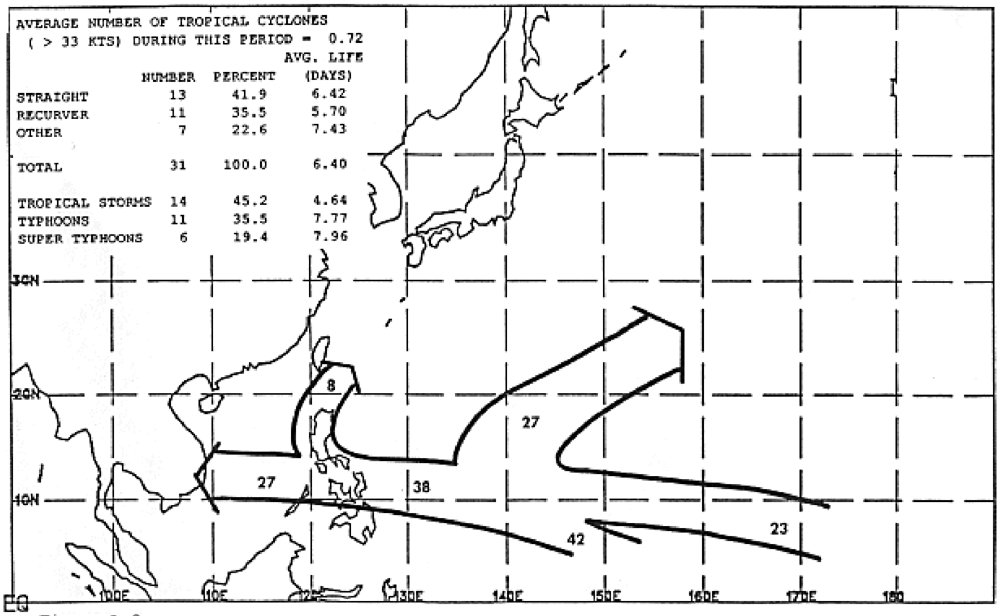

Figure A-2.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored.

MEAN PATHS FOR JAN 9 - JAN 23

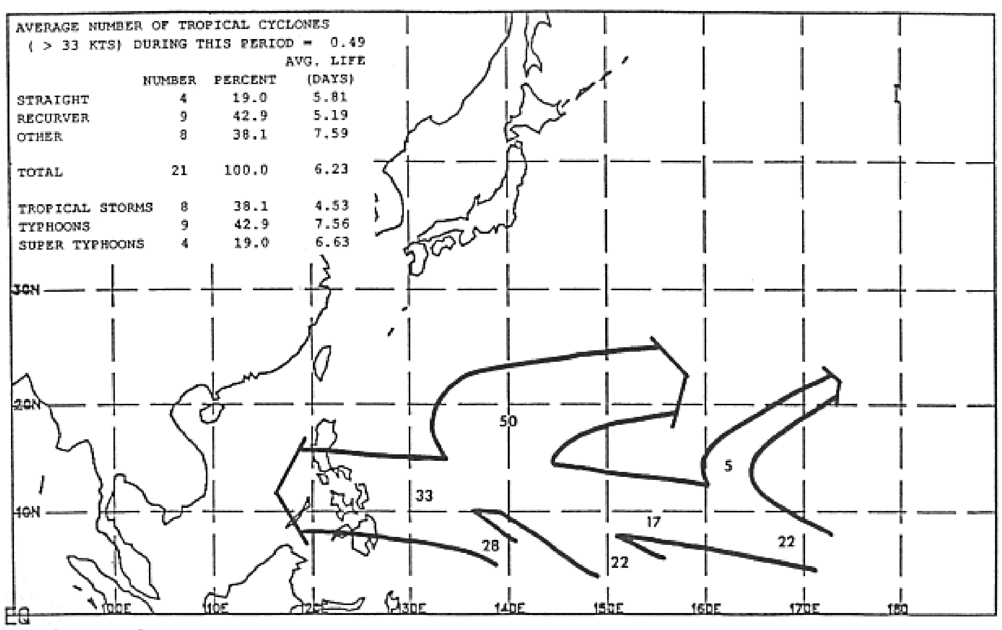

Figure A-3.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored.

MEAN PATHS FOR JAN 24 - FEB 8

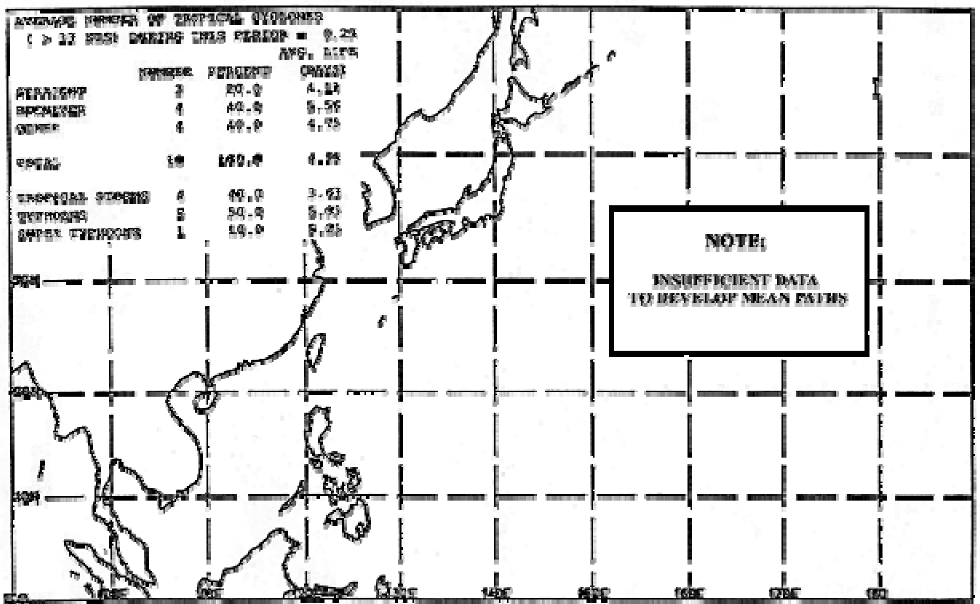

Figure A-4.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored.

MEAN PATHS FOR FEB 9 - FEB 23

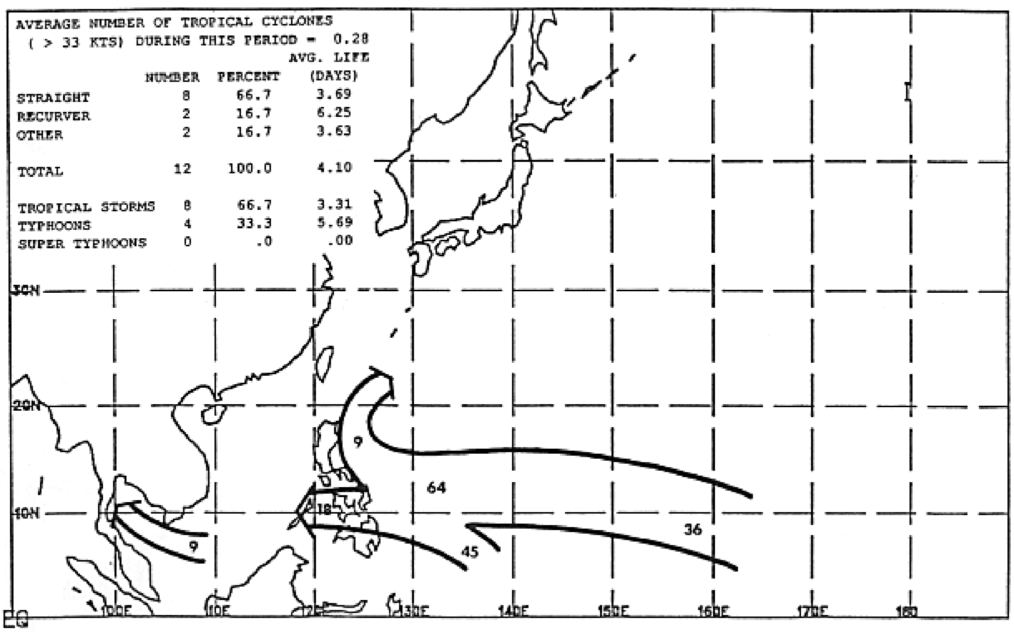

Figure A-5.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored.

MEAN PATHS FOR FEB 24 - MAR 8

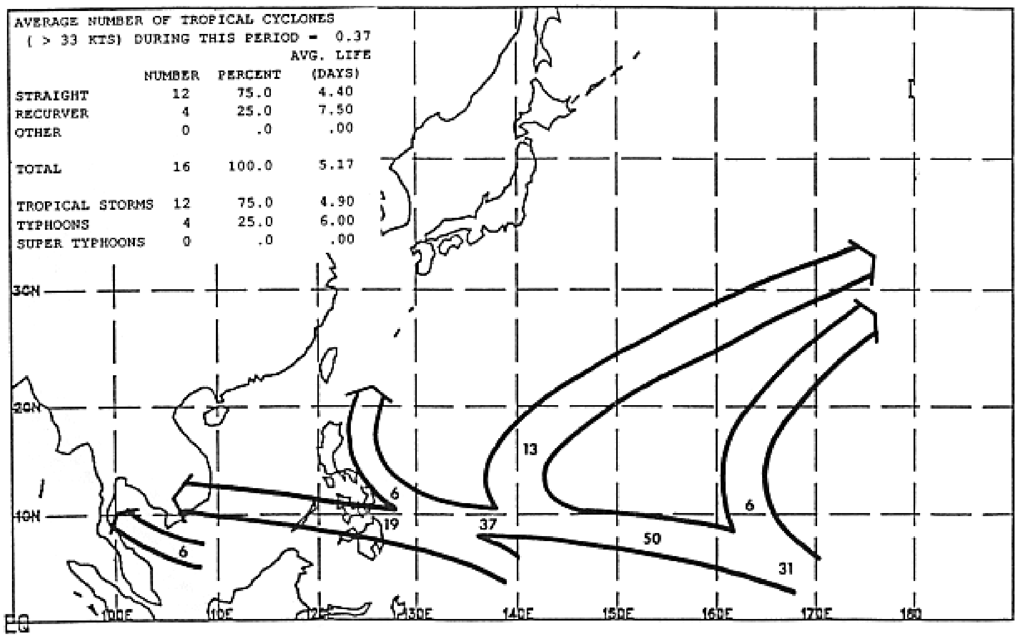

Figure A-6.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored.

MEAN PATHS FOR MAR 9 - MAR 23

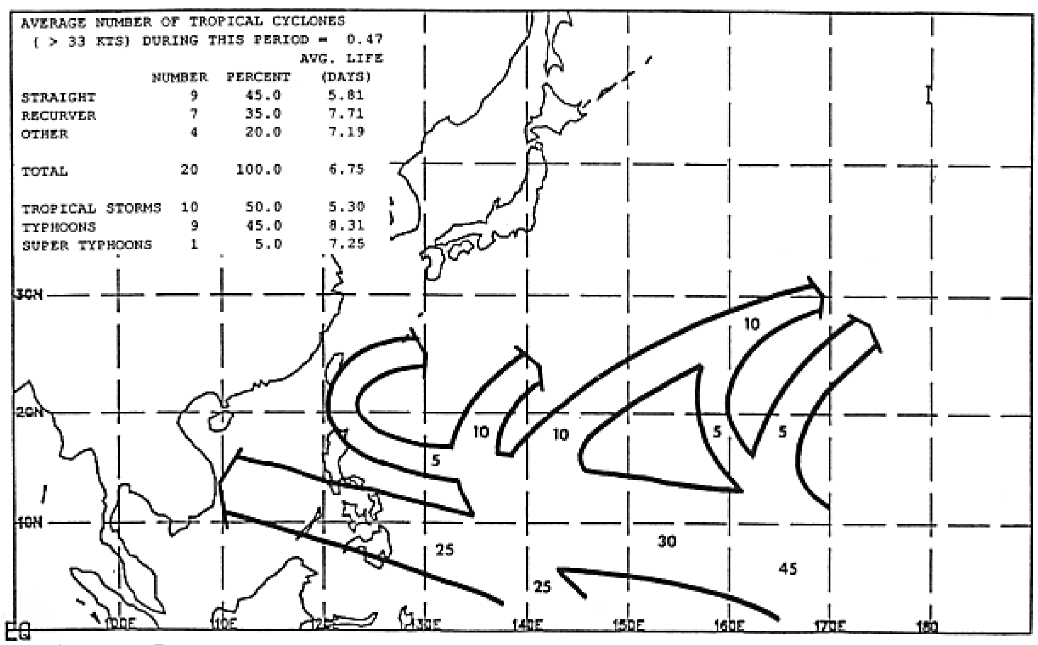

Figure A-7.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored.

MEAN PATHS FOR MAR 24 - APR 8

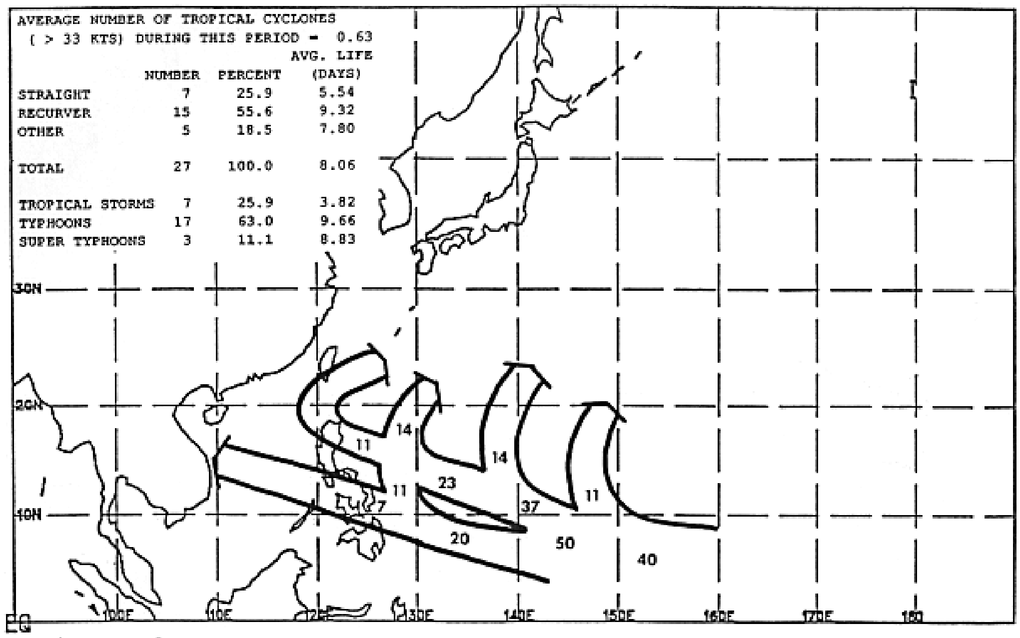

Figure A-8.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored.

MEAN PATHS FOR APR 9 - APR 23

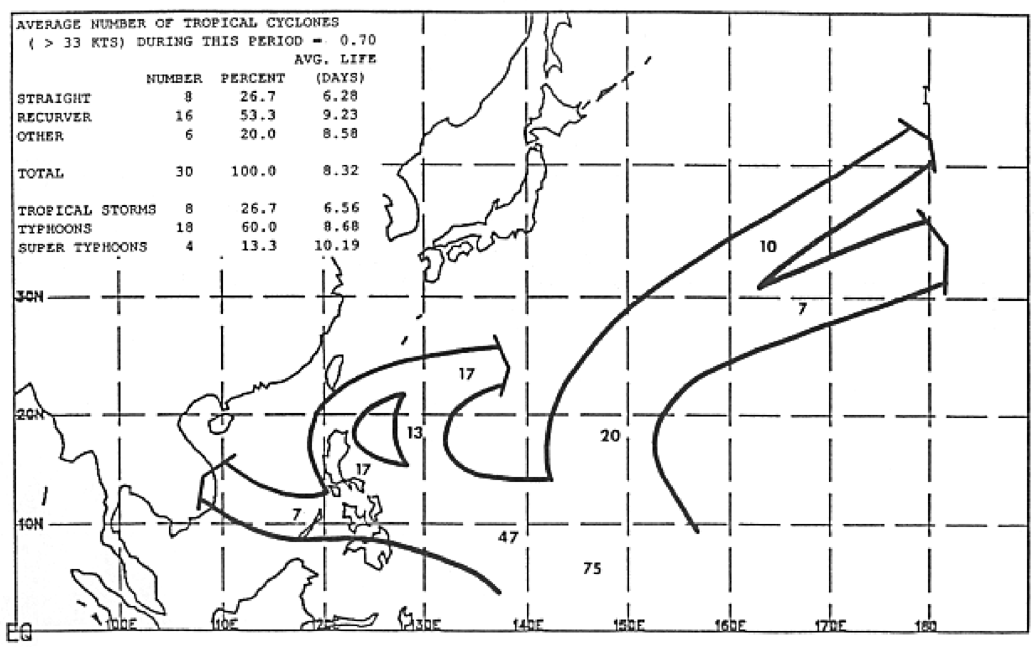

Figure A-9.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored.

MEAN PATHS FOR APR 24 - MAY 8

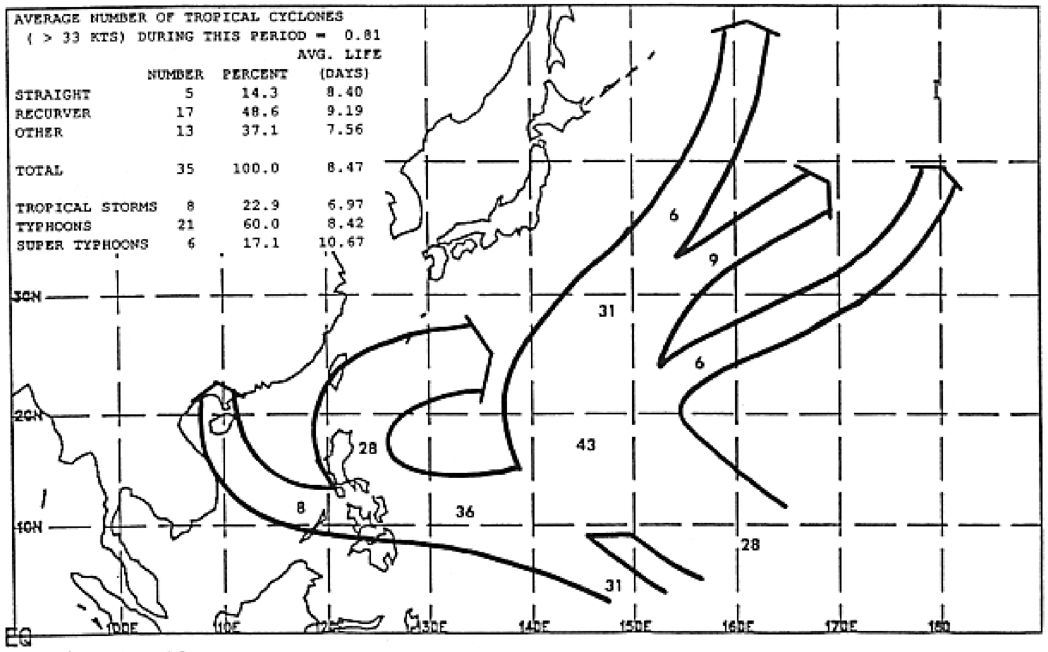

Figure A-10.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored.

MEAN PATHS FOR MAY 9 - MAY 23

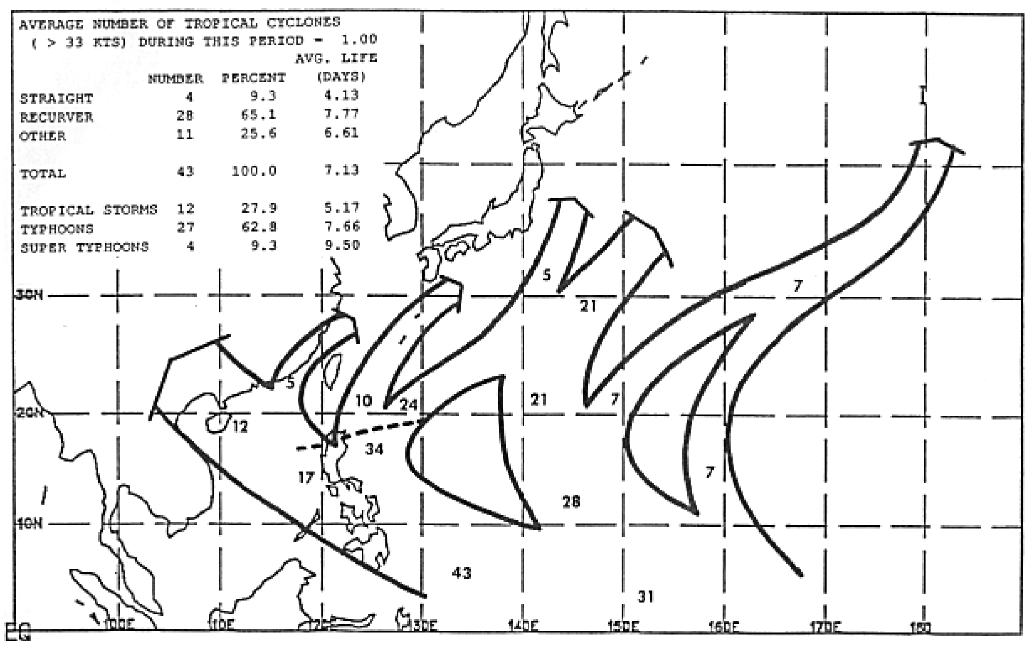

Figure A-11.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR MAY 24 - JUN 8

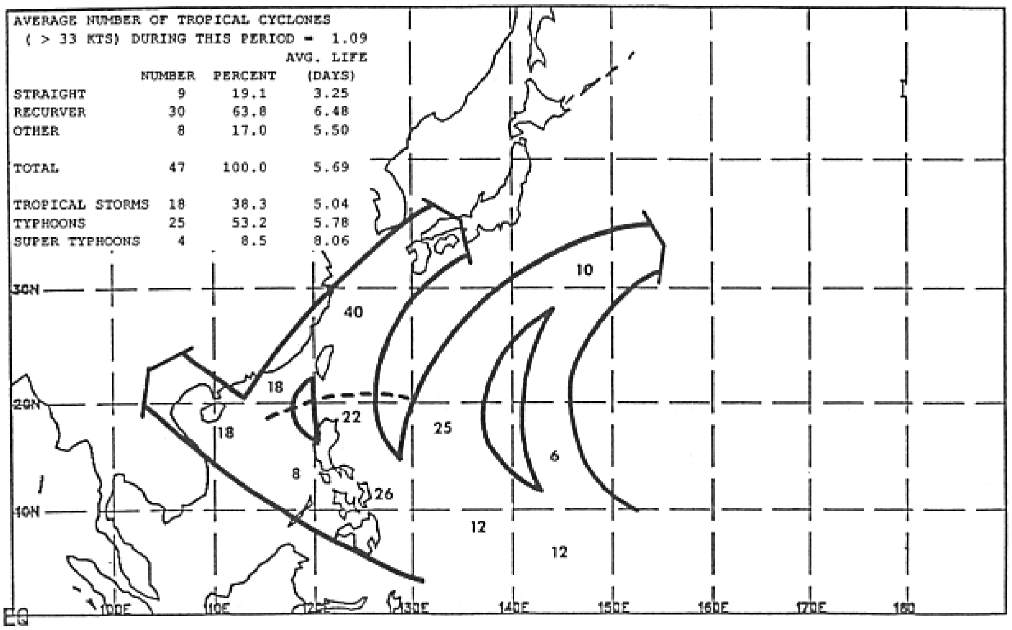

Figure A-12.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR JUN 9 - JUN 23

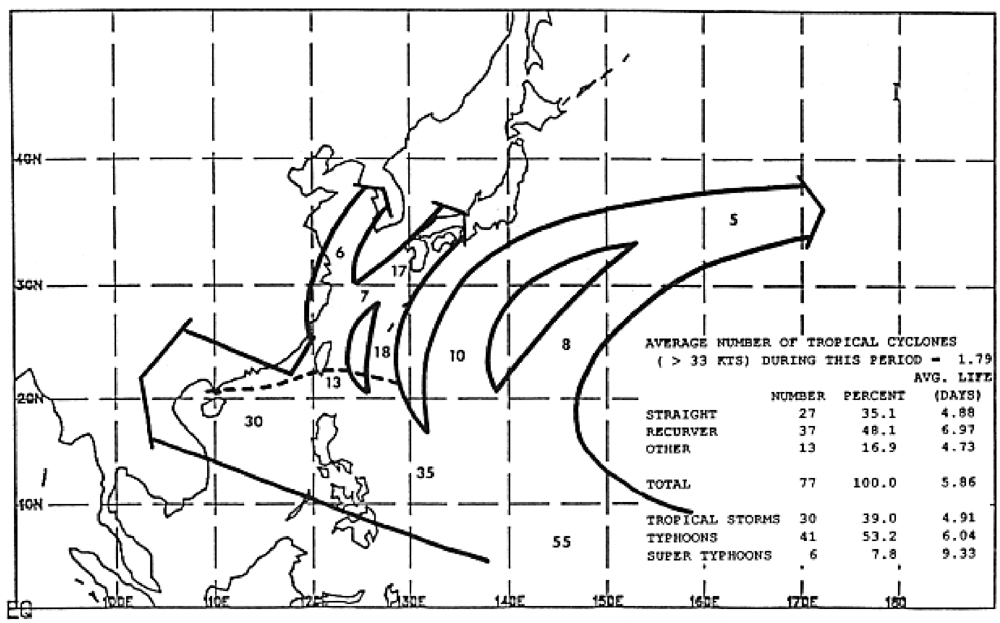

Figure A-13.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR JUN 24 - JUL 8

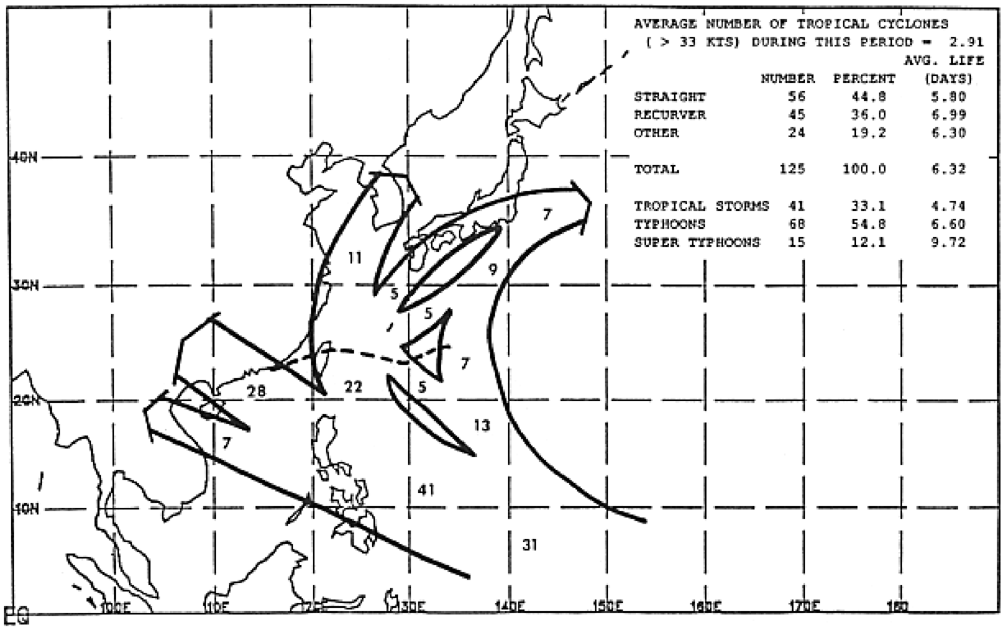

Figure A-14.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR JUL 9 - JUL 23

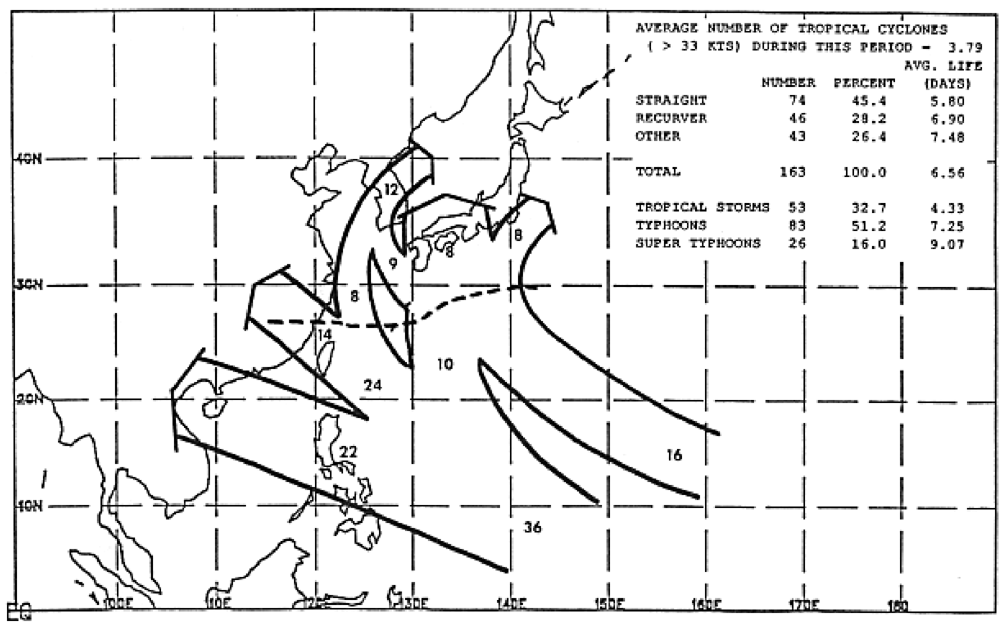

Figure A-15.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR JUL 24 - AUG 8

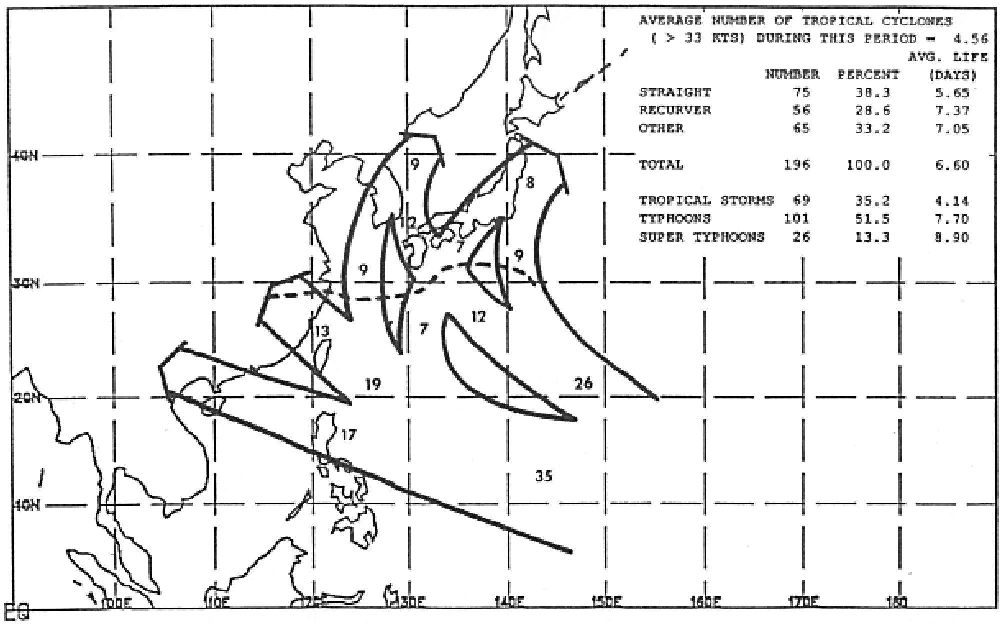

Figure A-16.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR AUG 9 - AUG 23

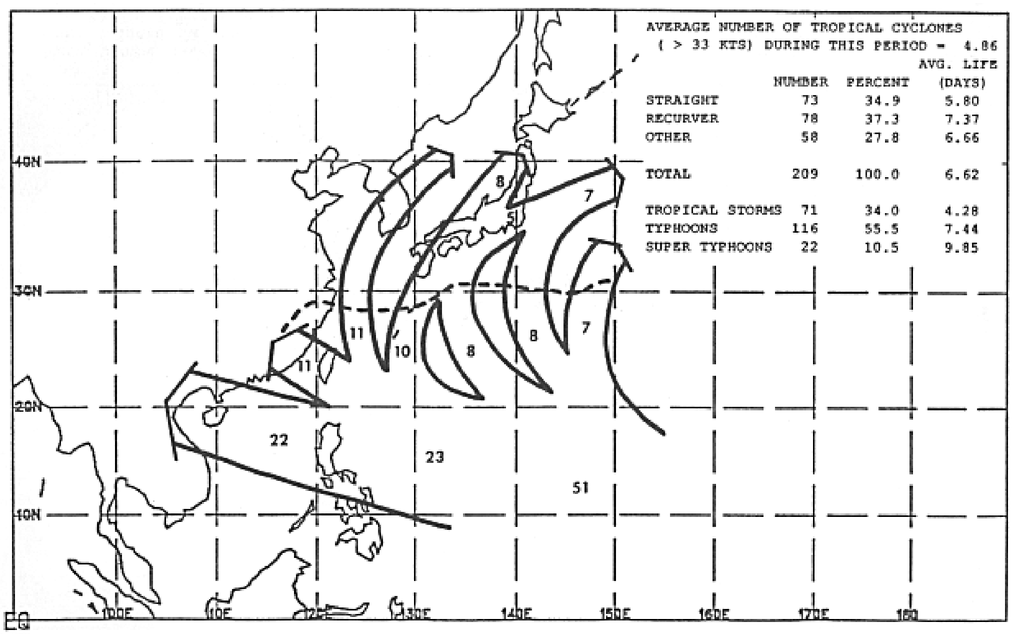

Figure A-17.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR AUG 24 - SEP 8

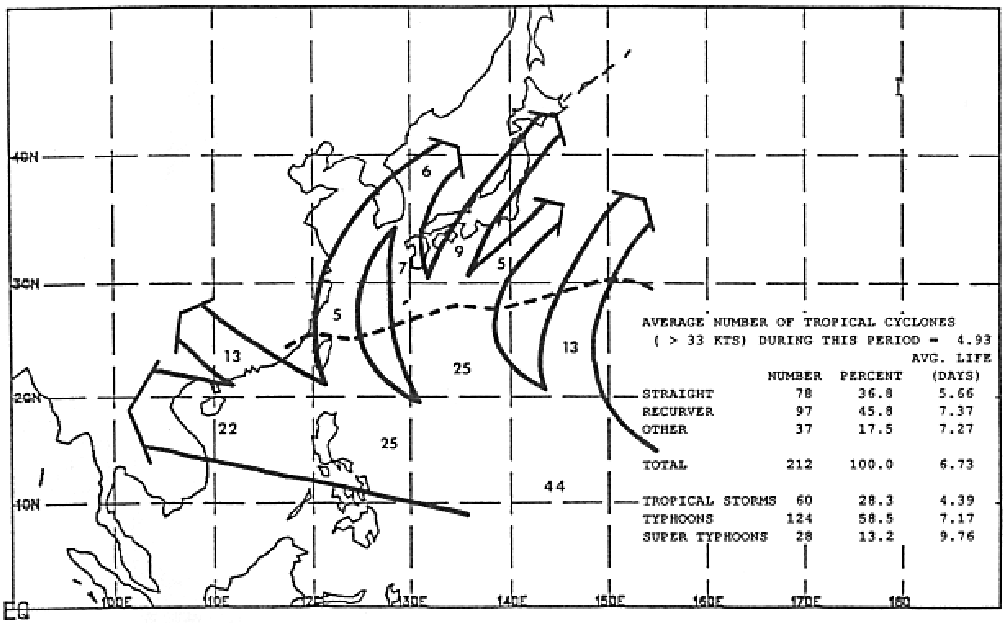

Figure A-18.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR SEP 9 - SEP 23

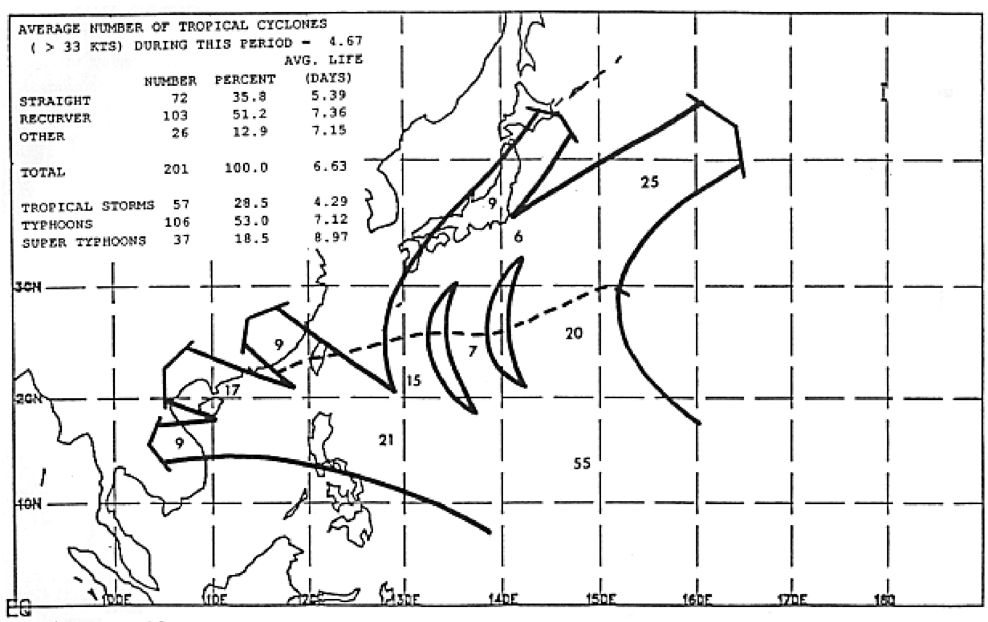

Figure A-19.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR SEP 24 - OCT 8

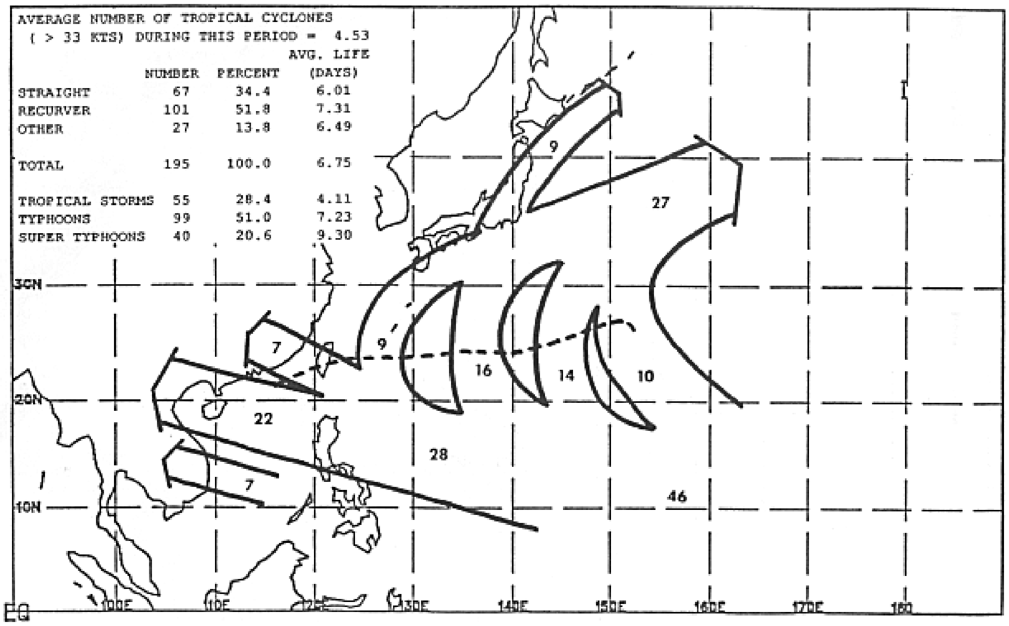

Figure A-20.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR OCT 9 - OCT 23

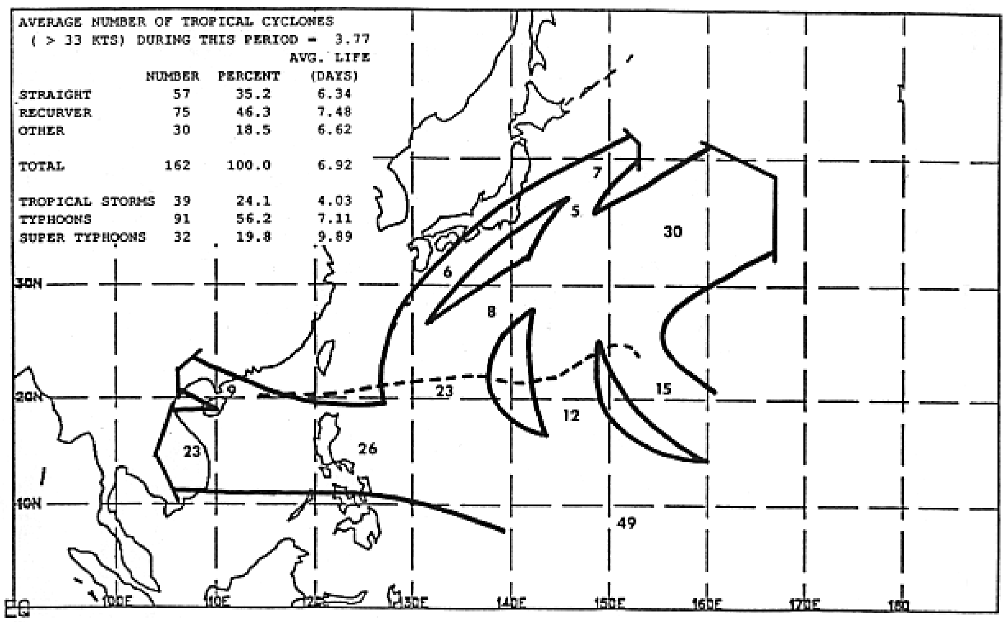

Figure A-21.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR OCT 24 - NOV 8

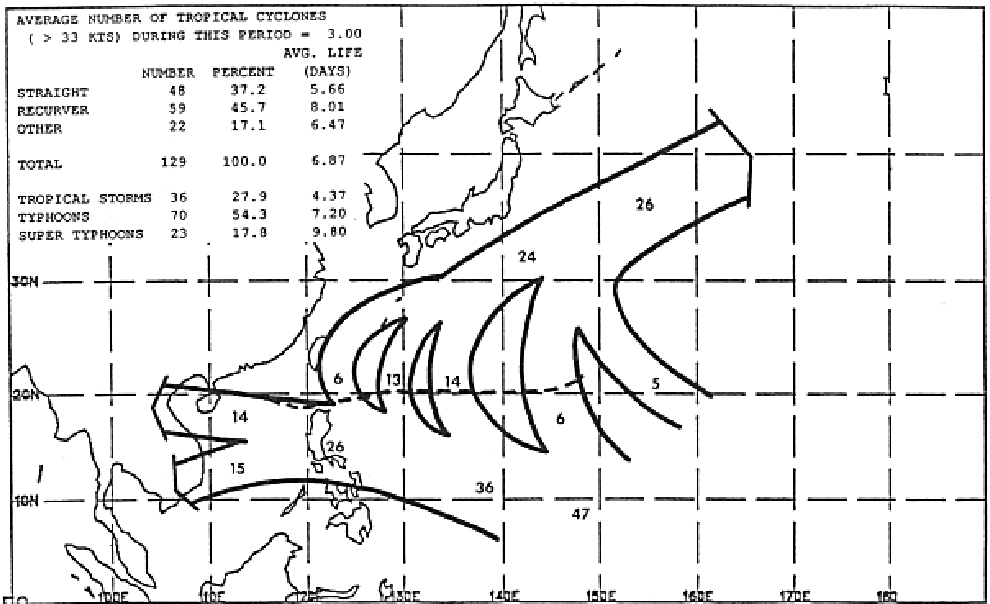

Figure A-22.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR NOV 9 - NOV 23

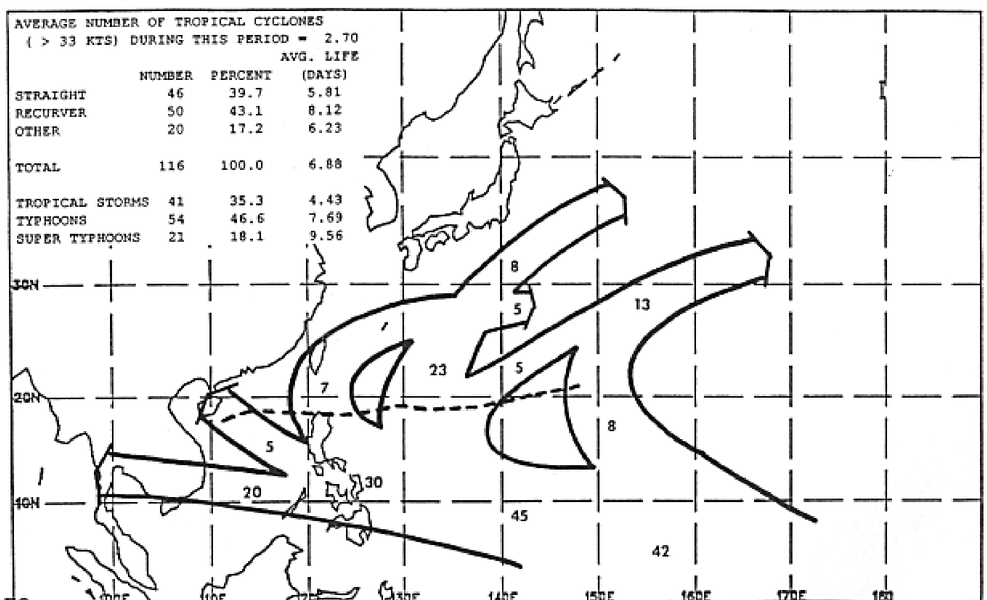

Figure A-23.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR NOV 24 - DEC 8

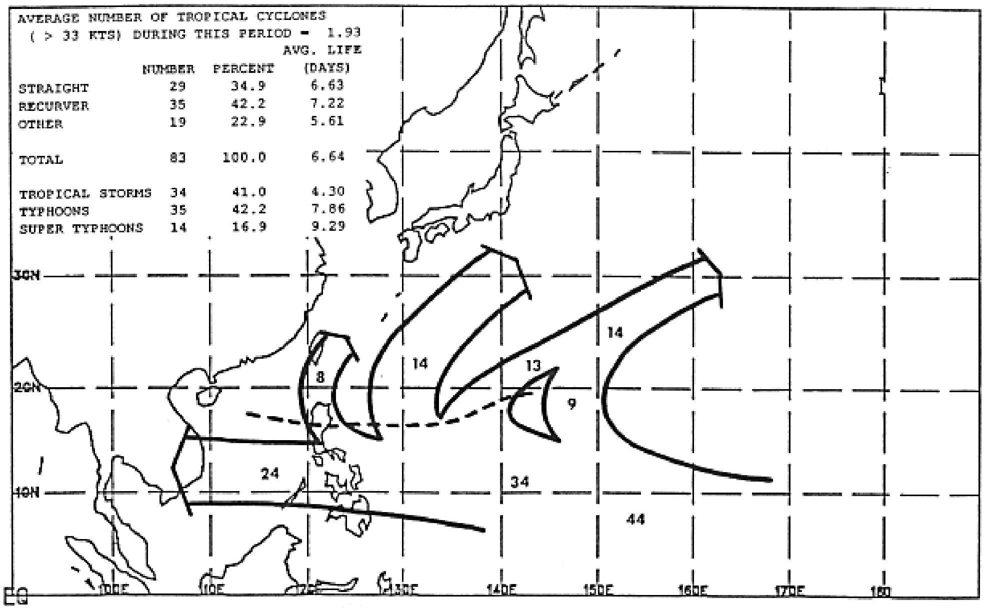

Figure A-24.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

MEAN PATHS FOR DEC 9 - DEC 23

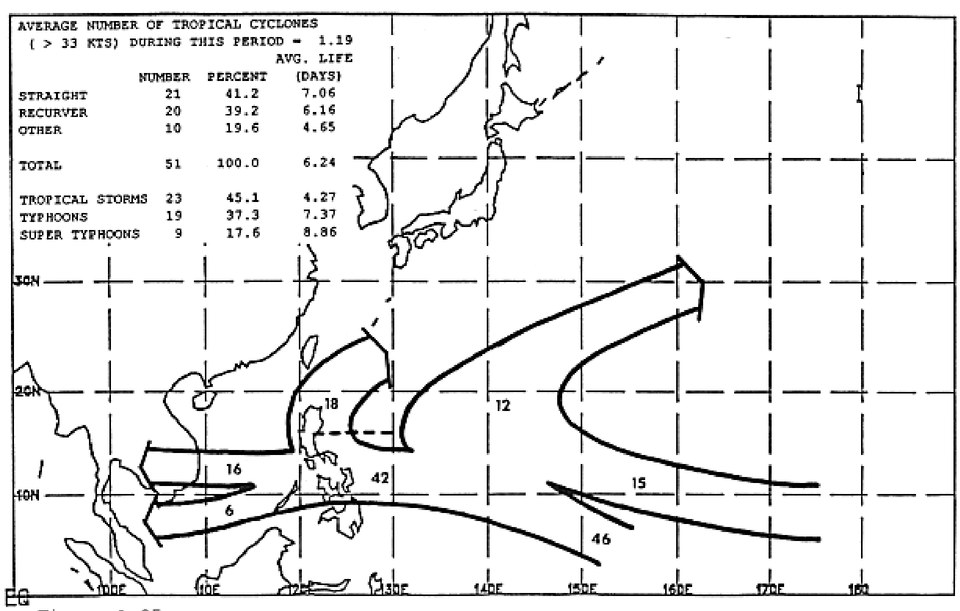

Figure A-25.
Mean tropical cyclone (> 33 kts) path. Numbers represent the percentage of tropical cyclones (> 33 kts) which followed the indicated path. These numbers may not add up to 100% since not all tropical cyclones (> 33 kts) follow a mean path and some develop/dissipate along a path. Tracks which contained less than 5% of the tropical cyclones (> 33 kts) are ignored. Dashed line represents mean recurvature position of tropical cyclones (> 33 kts) classified as recurvers.

APPENDIX C
Climatology for Yokosuka, Japan

1. Temperature and Precipitation:

a. Average Maximum/Minimum Temperature.

Temperature (°F)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Maximum	50	55	64	71	76	82	86	79	69	61	61	54
Avg. Minimum	36	37	41	50	58	65	71	74	61	58	50	41
Avg. Extreme Maximum	73	76	82	90	101	102	105	100	90	81	77	
Avg. Extreme Minimum	21	19	24	32	41	50	56	60	54	42	28	25

b. Average Percent Relative Humidity. (RH%)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RH%	62	64	68	73	76	83	84	82	82	77	71	65

c. Average Amount of Rainfall/Snowfall in inces. (INS)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (INS)	2.0	3.0	2.0	6.0	7.0	8.0	6.0	6.0	8.0	8.0	5.0	2.0
Snowfall (INS)	1.0	2.0	1.0	0	0	0	0	0	0	0	0	0

d. Average Number of Days with Precipitation.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days	9	10	15	15	15	18	16	13	17	16	12	9

e. Average Number of Days with Snowfall.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days	1	1.6	.4	0	0	0	0	0	0	0	0	3

f. Maximum Snowfall Accumulation in inches (INS).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24 hr Max (INS)	16.0	8.0	13.0	0	0	0	0	0	0	0	0	14.0
Max Depth	16.0	8.0	13.0	0	0	0	0	0	0	0	0	14.0

2. Winds

a. Average Wind Direction and Speed (kts).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Direction	N	N	NNE	SSW	SSW	SSW	SSW	NNE	N	N	N	NNE
Speed (kts)	11	11	11	11	11	10	10	10	11	12	11	10

b. Average/Max Wind Speed (kts).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Speed	7	7	7	8	7	7	6	7	6	6	6	6
Avg. Max Speed	15	16	16	19	17	16	12	14	14	15	15	15
Max Speed	25	28	28	35	26	29	19	22	25	40	28	23
Prevailing Direction	S	S	S	S	S	S	S	S	S	ENE	E	S

c. Peak Wind Gusts Direction and Speed (kts).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Direction	240	230	340	220	330	220	240	220	210	190	230	340
Speed (kts)	45	56	55	58	44	53	33	39	45	68	42	43

d. Number of Days with Wind Gusts Greater Than:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
>20 kts	3.0	14.0	13.0	16.0	14.0	10.0	6.0	8.0	8.0	7.0	9.0	12.0
>30 kts	3.0	4.0	4.0	7.0	4.0	4.0	1.0	2.0	1.0	2.0	3.0	5.0

3. Thunderstorms

a. Number of Days with Thunderstorms.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days	0.0	0.0	0.0	1.0	0.0	0.0	3.0	1.0	0.0	0.0	0.0	0.0

4. Fog.

a. Number of Days with Fog.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days	1.0	1.0	1.0	2.0	2.0	4.0	3.0	3.0	1.0	1.0	1.0	1.0

5. Visibility.

a. Number of Days with Visibility Less Than.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<8 km	6.0	7.0	11.0	12.0	12.0	20.0	22.0	21.0	15.0	10.0	7.0	4.0
<5 km	5.0	5.0	9.0	10.0	9.0	16.0	20.0	17.0	11.0	8.0	7.0	3.0
<1 km	3.0	3.0	4.0	6.0	5.0	8.0	8.0	7.0	4.0	4.0	3.0	2.0

6. Cloud Coverage.

a. Average Cloud Cover in Eighths.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Cloud Cover	4.0	5.0	6.0	6.0	6.0	7.0	6.0	6.0	6.0	5.0	5.0	4.0

7. VFR/IFR Conditions.

a. Percentage of Days with VFR/IFR and Below Field Minimum Conditions.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
VFR	90.0	87.0	84.0	80.0	80.0	65.0	61.0	73.0	79.0	85.0	87.0	94.0
IFR	6.0	6.0	9.0	11.0	12.0	19.0	24.0	17.0	14.0	10.0	8.0	3.0
Below Mins	4.3	7.0	7.0	9.0	8.0	16.0	15.0	10.0	7.0	6.0	5.0	3.0

APPENDIX D
Climatology for Sasebo, Japan

JANUARY	AVG	MAX	MIN	DIRECTION	SPEED
TEMP °F	42	54	37		
PRECIP	3.20	9.69	0.98		
AVG WIND				310	08
FEBRUARY	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	42	53	36		
PRECIP	3.82	8.66	1.23		
AVG WIND				330	10
MARCH	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	47	56	39		
PRECIP	5.42	10.12	1.58		
AVG WIND				030	08
APRIL	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	55	65	46		
PRECIP	7.00	11.74	1.10		
AVG WIND				090	06
MAY	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	63	74	53		
PRECIP	7.42	13.51	1.84		
AVG WIND				100	06
JUNE	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	70	80	65		
PRECIP	13.75	25.58	2.18		
AVG WIND				120	05
JULY	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	76	84	73		
PRECIP	12.71	33.21	0.50		
AVG WIND				260	08
AUGUST	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	80	86	73		
PRECIP	8.64	27.30	0.84		
AVG WIND				240	10
SEPTEMBER	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	73	80	68		
PRECIP	8.57	24.12	2.72		
AVG WIND				270	08
OCTOBER	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	64	70	54		
PRECIP	3.60	8.98	0.69		
AVG WIND				290	08
NOVEMBER	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	54	66	47		
PRECIP	3.35	8.04	0.51		
AVG WIND				310	08
DECEMBER	**AVG**	**MAX**	**MIN**	**DIRECTION**	**SPEED**
TEMP °F	46	59	41		
PRECIP	2.48	5.08	0.17		
AVG WIND				330	08

APPENDIX E
Rain vs. Snow Worksheet

1. Steps to determine rain vs. snow:

_______	Snow	2828-2795 meters	2797-2785 meters
_______	Snow	2796 meters or less	2784 meters or less

2. Synoptic Indications:

Rain	_______
Freezing Rain	_______
Mixed	_______
Snow	_______

3. Freezing Level: 1200 feet or higher = Rain _______

1200 feet or lower = Snow _______

4. Thickness Values:

a. 1000-850 mb

		Low south of Japan	Leeside Trough
_______	Rain	1308 meters or more	1303 meters or more
_______	Mixed	1307-1290 meters	1303-1295 meters
_______	Snow	1289 meters or less	1294 meters or less

b. 1000-700 mb

		Low south of Japan	Leeside Trough
_______	Rain	2829 meters or more	2798 meters or more
_______	Mixed		

c. 1000-500 mb

		Low south of Japan	Leeside Trough
_______	Rain	5381 meters or more	5287 meters or more
_______	Mixed	5380-5326 meters	5286-5261 meters
_______	Snow	5325 meters or less	5260 meters or less

d. 850-700 mb Low south of Japan Leeside Trough

_______	Rain	1522 meters or more	1500 meters or more
_______	Mixed	1521-1500 meters	1499-1490 meters
_______	Snow	1499 meters or less	1489 meters or less

4. Forecasted temperature, dew point and wet bulb at surface prior to onset of precipitation. (use graph 1, Figure 7.5 for the wet bulb)

Temperature: _______ Dew point: _______ Wet bulb: _______

a. Evaporation cooling of surface temperatures:

Surface temperature before onset of precipitation _______ Deg F.

Initial temperature decrease at onset - 2 Deg F
Subtract 1 degree F for each 1000 Feet
above 3000 feet until you reach cloud ceiling:_______ Deg F
Forecast minimum temperature: _______ Deg F

b. Compare the results of section A with thickness values paragraph 3

Snow = less than 33.7 Deg F.
Mixed = 33.8 – 38.5 Deg F. (see note 2)
Rain = 37.8 Deg F or greater (see note 3)

5. 850 mb Temperature/dewpoint/wetbulb

a. Temperature Current _______ Deg C Forecast _______ Deg C (note 4)

-03 Deg C or warmer = Rain _______ Deg C
-07 Deg C or colder = Snow _______ Deg C

b. Dew point Current _______ Deg C Forecast _______ Deg C (note 5)

c. Wet Bulb Current _______ Deg C Forecast _______ Deg C
(use graph II for forecasted wet bulb)

6. 700 mb Temperature
(Use top of Mt. Fuji as basis for hourly 700 mb temperature check)

-11 Deg C or lower = Snow
-10 Deg C or warmer = Rain

7. Using the forecast surface wet bulb (step 4) and forecast 850 mb wet bulb (step 5C), enter values in graph III and determine the type of precipitation.

Rain _______ Freezing Rain ______ Mixed Precip _______ Snow _______

8. Boundary layer winds (best if actual PPBB U/A report is used)

1000 ft __________ 2000 ft __________ 3000 ft __________

Northwest through Northeast = Favorable for snow

9. Forecast Tally

Step	Rain	Freezing Rain	Mixed	Snow	Actual
1.	_____	_____	_____	_____	_____
2.	_____	_____	_____	_____	_____
3A.	_____	_____	_____	_____	_____
3B.	_____	_____	_____	_____	_____
3C.	_____	_____	_____	_____	_____
3D.	_____	_____	_____	_____	_____
4.	_____	_____	_____	_____	_____
5.	_____	_____	_____	_____	_____
6.	_____	_____	_____	_____	_____
7.	_____	_____	_____	_____	_____
8.	_____	_____	_____	_____	_____

10. Verification remarks:

____
____
____
____
____
____

Remarks should include such notations a: snow began 1500I; temperature was 40 degrees, changed to rain and snow mixed at 1800I, etc...

2. Steps for snow:

1. Determine the 1000-500 mb thickness in meters from the latest upper air sounding. The station selected will depend upon the advection pattern, but it is highly recommended that HAMAMATSU (47681) to TATENO (47646) be used for best results.

2. Enter column Hs of table A1 (precipitable water (w) and corresponding thickness (Hs) with the computed 1000-500 mb thickness in meters. Determine the amount of precipitable water from column W.

3. Multiply this figure (W in inches) by 10 to arrive at the accumulation of snow which should be forecast (Assume a snow to rain ration of 10:1).

Sounding used:
Station: __________ Date/Time: __________

From step 1: 1000-500 mb thickness in meters: _____

From step 2: Precipitable water (W) from table 1: _____

From step 3: W times 10 (10W): _____

APPENDIX F
Meteorology Terminology

1. Clouds.

Clear - Less than one-eighth of the sky is covered by clouds.
Scattered - One-eighth trough four-eighths of the sky is covered by clouds.
Broken - Five-eighths through seven-eighths of the sky is covered by clouds.
Overcast - more than 7/8th of the sky is covered (breaks in the clouds may be present).
Clearing - Cloudiness decreasing markedly during the forecast period (decreases by at least four-eighths).
Decreasing Cloudiness - Progressively decreasing sky (cloud) cover.
Partial Clearing - A portion of the sky clearing, as from overcast to broken (eight-eighths to five-eighths coverage).
Increasing Cloudiness - Progressively increasing sky (cloud) cover.

2. Precipitation.

Rain - Liquid water particles, either large or small, which fall to the surface in a continuous manner.
Rain Showers - Liquid water particles, either large or small, which falls to the surface with rapid changes in intensity.
Drizzle - Fine drops of liquid, very close together which float with air currents and slowly reach the ground.
Snow - Ice crystals, mostly branched in the form of a six pointed star.
Hail - Small balls or pieces of ice (hail stones), falling separately or frozen together in irregular lumps. Hail is normally associated with thunderstorms and surface temperatures above freezing.

3. Classification of Precipitation by Frequency.

Intermittent - Precipitation that stops and restarts at least once within each hour. Normally falls from stratocumulus or stratus type clouds.
Continuous - Intensity that changes gradually, if at all. Normally falls from stratus type clouds.
Showers - Precipitation that changes intensity or starts and stops abruptly. Showers normally fall from cumuliform type clouds.

4. Precipitation Intensities (rain).

Slight - Individual drops are easily identifiable, spray over hard surfaces is slight; pools form very slowly; over 2 minutes may be required to wet decks and similar dry surfaces; visibility not reduced or reduced slightly.
Moderate - Individual drops are not clearly identifiable, some spray over hard surfaces; pools form rapidly; visibility is reduced.
Heavy - Individual drops are not clearly identifiable; seemingly in sheets, heavy spray to a height of several inches is observable over hard surfaces; visibility is greatly reduced.

5. Precipitation Intensities (snow vs. drizzle).

Slight - Visibility five-eighth statute mile or more.
Moderate - Visibility less than five-eighth statute mile but not less than five-sixteenth statute mile.
Heavy - Visibility less than 45 percent coverage.

6. Frequency of Showers by Coverage.

Isolated - 1 or 2 percent.
Widely Scattered - 3 to 15 percent.
Scattered - 16 to 45 percent.
Numerous - Greater than 45 percent coverage.

7. Wind.

Wind - The horizontal motion of air past a given point.
Wind Direction - the direction FORM which the wind is blowing.
Variable Wind Direction - Wind direction that fluctuates by 30 degrees or more during the period of the observation.
Gust - Rapid fluctuation in wind speed with a variation of 10 knots or more between peaks and lulls.
Squalls - A sudden increase of wind speed by at least 15 knots and sustained at 20 knots or more and lasting for at least 1 minute.
Wind Shift- a change in wind direction of 45 degrees or more, which takes place in less than 15 minutes.
Veering - A clockwise change in wind direction.
Backing - A counter-clockwise change in wind direction.
Calm - 0 to 1 knot (Beaufort force 0)
Light Air - 1 to 3 knots (Beaufort force 1)
Light Breeze - 4 to 6 knots (Beaufort force 2)
Gentle Breeze - 7 to 10 knots (Beaufort force 3)
Moderate Breeze - 11 to 16 knots (Beaufort force 4)
Fresh Breeze - 17 to 21 knots (Beaufort force 5)

Strong Breeze - 22 to 27 knots (Beaufort force 6)
Near Gale - 28 to 33 knots (Beaufort force 7)
Gale - 34 to 40 knots (Beaufort force 8)
Strong Gale - 41 to 47 knots (Beaufort force 9)
Storm - 48 to 55 knots (Beaufort force 10)
Violent Storm - 56 to 63 knots (Beaufort force 11)
Typhoon- +64 knots (Beaufort force 12-17)

8. Pressure Systems

Anticyclone - A clockwise circulation (Northern Hemisphere), counter-clockwise circulation (Southern Hemisphere). Associated with high pressure and generally good weather.

Cyclone - A counter-clockwise circulation (Northern Hemisphere), clockwise circulation (Southern Hemisphere). Associate with low pressure and generally poor weather.

Ridge - An elongated area of relatively high pressure that extends from the center of a high. The wind circulation is essentially anticyclonic. Usually associated with fair weather.

Trough - An elongated area of relatively low pressure that extends from the center of a low. The wind circulation is essentially cyclonic. Usually associated with poor weather.

Lee Trough - a pressure trough formed on the lee side of a mountain range or an island across which the wind is blowing almost perpendicular.

9. Fronts.

Cold Front - A line of discontinuity along which a wedge of cold air is underpinning and displacing warm air. Cold fronts are normally located in well-defined pressure troughs whenever there is a marked temperature contrast between 2 adjacent air masses.

Warm Front - A line of discontinuity where the forward edge of a warm air mass is replacing a retreating cold air mass. Warm fronts are generally located in pressure troughs, although these troughs are not as well defined as those in which cold fronts are located.

Occluded Front - Occlusions are a combination of overtaking cold and warm fronts. The resulting weather is a combination of the conditions, which exist with both frontal types.

Quasi-stationary Front - This type of front is one along one air mass does not appreciably replace the other.

10. Sea and Swell.

Sea - Wind waves observed within their generating area (fetch), with the wave direction generally that of the local wind direction. Wind waves (sea), as opposed to swell, have sharper peaks and irregular appearance.

Swell - Ocean waves that have traveled out of their generating area. Swell characteristics exhibit a more regular and longer period and have a flatter rest than waves within a fetch area. They are no longer under the influence of the wind that generated them.

Combined Seas - Combined seas and swell given as the significant height (in feet) of the waves when the sea and swell are combined.

Significant Height (Waves) - Average height of the highest one-third of the waves of a given wave group. Forecasts for sea, swell and surf are always given as a significant height.

Wave Direction - Direction *from* which the waves are coming.

Wave Height - Vertical differences between the wane trough and the wave crest.

Wave Period - Time (in seconds) between the passage of two consecutive wave crests (or troughs) past a fixed point.

11. Surf.

Surf - Waves that break along a shore or reef.

Surf Height - the height of a breaking wave (surf) measured from the trough to crest in terms of significant height.

12. Tropical Meteorology

Eye - The relatively calm area that occurs in the center of a tropical cyclone. Size may vary form approximately 1 NM to over 45 NM and there may be a concentric eye, as the outer eyewall collapses and an inner eyewall forms. The presentation of an unusual phenomenon in the very heart of this typhoon - a double band of cloud around the eye and is seen in very intense cyclones and causes a chain reaction within the storm. When the outer eye develops, it steals moist air as it is sucked radially into the storm, leaving the inner eye to shrink and collapse. Pressure in the very center of the cyclone can rise 30 mb in as little as six hours when the concentric eyewall develops because convection is no longer happening there. It is taking place within the outer eyewall and the inner eye literally dries up as moist air is channeled around it. When the inner eye fades, the outer eye becomes the main centre of the storm. At this point the cyclone's eye is very large and the whole storm slows down.

Feeder Band - Intense bands of clouds and rain spiraling counter-clockwise (clockwise in the Southern Hemisphere) in towards the center of a tropical cyclone. The term “feeder bands” is a misnomer because they actually act to destroy tropical cyclones by robbing the center of energy through outgoing gravity waves.

Intertropical Convergence Zone (ITCZ) - A zone of convergence between the northeast trades of the Northern Hemisphere and the southeast trades of the Southern Hemisphere. The ITCZ is also referred to as a zone of inter-tropical confluence (ITC), the equatorial trough, and the equatorial front or the intertropical front.

Line of Convergence - A line or area in which the horizontal wind field is converging (coming together). Often associated with cloudiness and precipitation.

Tropical Wave - Sometimes referred to as an “Easterly Wave”, is defined as a trough or a cyclonic curvature maximum located in the easterly trade winds.

Tropical Cyclone - A non-frontal low-pressure system of synoptic scale, developing over tropical or sub-tropical waters and having a definite organized circulation. Tropical depressions, tropical storms and typhoons are tropical cyclones.

Tropical Depression - A tropical cyclone in which the maximum sustained surface winds (1-minute mean) is 33 knots or less.

Tropical Disturbances - A discrete system of organized and persistent convection (generally 80-280 NM in diameter) originating in the tropics or sub-tropics, having a non-frontal migratory character and having maintained its identity for 24 hours or more. These systems may or may not be associated with a detectable cyclone, the basic generic designation that, in successive states of intensification, may be classified as a tropical depression, storm or typhoon.

Tropical Storm - A tropical cyclone with maximum sustained surface winds (1-minute mean) in the range of 34 to 63 knots.

Typhoon/Hurricane - a tropical cyclone in which maximum sustained surface winds (1-minute mean) ranges form 64-129 knots, inclusive. East of 180 degrees, they are called hurricanes, while to the west they are referred to as typhoons. Typhoons with winds of 130 knots or greater are classified as super typhoons. Foreign governments use these or other terms for tropical cyclones and may apply different intensity criteria.

Wall Cloud - The wall of clouds that forms in the pheriphery of the eye and defines the eye. There is no eye without an eyewall. The wall cloud contains the most severe weather and highest winds of a tropical cyclone.